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MARIOUT BARLEY

WITH A DISCUSSION OF BARLEY CULTURE IN CALIFORNIA

BY
G. W. HENDRY

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By G. W. HENDRY

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INTRODUCTION

Barley is the leading cereal crop of California, and is grown and fed here in larger quantities than in any other state. The average disposition of the crop has been about as follows:

	Per cent
Fed and used for seed in California	53
Exported	37
Used for malting	10

Commensurate with the economic importance of the crop, however, comparatively little advancement in tillage methods has been made, and it is not a little curious that only one variety is extensively grown and this, the Coast or common barley, constitutes more than 99 per cent of the entire production of the state. Obviously this is an error in itself, for the excellent reason that no single variety could conceivably outyield all other varieties, under the diversity of soils and climates existing within the barley producing areas of the state.

Concerning the origin of Coast or common barley we have no exact records to refer to, but inasmuch as barley of an identical type has long been grown in the south of Spain, it is not improbable that it found its way to California from that region, through the agency of the Spanish conquerors and the missionaries who followed them. Further evidence of this is supplied by the knowledge that this variety was grown from the earliest times about the mission settlements in California. Common (Coast) barley is well adapted to Pacific Coast conditions, but why it should have been grown here practically to the exclusion of all other varieties is difficult to explain, especially in view of the fact that several other varieties have been found to excel it in producing capacity.

Our present purpose is to awaken a general interest in the subject of barley improvement, and especially to introduce the variety Mariout (Calif. no. 2241). It is no part of our purpose to replace the common variety with Mariout, but rather to supplement it under the special conditions to which Mariout is better adapted, and thus widen the range of successful barley culture in California.

AGRICULTURAL HISTORY OF MARIOUT BARLEY

But a mere fragment of the early history of Mariout barley has come down to us from antiquity. It is said to have been extensively grown by the Romans during their occupation of the Mariut Lake region, south of Alexandria, Egypt, and skirting the Sahara Desert. While governing this region, referred to in Roman literature as

Fig. 1.—Representative grains of Mariout barley, left, and common (Coast) barley, right, enlarged 12 diameters. The two varieties are easily distinguishable by means of the rachilla (bristle) shown *in situ* at "A". The Mariout rachilla is bristly, the common rachilla is smooth. This character is constant under all conditions, and is a ready means of detecting mixture of the two varieties.

Mareotis, the Romans made some pioneer advances in the art of dry farming, and their quick perception of the drouth-resistant properties of Mariout barley is but another evidence of the acumen of this race in matters pertaining to agriculture.

The variety has been perpetuated since Roman times by the Bedouins, who introduced it into the arable regions of the Sahara Desert, where it has thrived in the dry desert heat. The production of it by the Bedouins has been attended by marked success, and their surplus production has been found an outlet in England and Scotland, where it has been used for malting purposes, and has fetched a premium over English-grown barley of about 10 shillings ($2.48) per quarter (8.24 bushels).

The first recorded appearance of Mariout in the United States occurred on November 7, 1903, when a sample of 240 pounds was received by the United States Department of Agriculture from Mr. Geo. P. Foaden of the Khedival Agricultural Society, Cairo, Egypt. This seed was assigned the S. P. I. (Seed and Plant Introduction) no. 9877, and later the C. I. (Cereal Investigation) no. 261. In 1904 it was distributed to the experiment stations in the arid western states, and the first planting was made in California at the Yuba City field station in December of that year. The first impression made by it in California was so unfavorable that it was discarded as being without promise in this state, and unworthy of further trial. By the greatest good fortune, however, a second sample of one-fourth pound was secured the following year through the courtesy of the E. Clemens Horst Company of San Francisco, who in turn had obtained it directly from their London office, and the present stock of Mariout in California is from this source. This sample bore no other designation than "Sample–1" (S–1) and was not suspected of being Mariout in another guise until near maturity, when its unmistakable characteristics disclosed its identity. In its second appearance it showed greater promise, and was sent to the University Farm forthwith for a more thorough trial, where it was grown in the cereal nursery under close observation until the year 1911, at which time its six years of good performance merited an advancement of it to the plot tests, in competition with the highest yielding varieties under field competition.

In its first year under field conditions it yielded at the astonishing rate of 126.6 bushels (63.3 sacks) per acre, greatly exceeding all other varieties in productivity for that season, and thereby establishing a record for high yield at the experiment station which has stood unequalled to this day. During the eight succeeding years, 1912 to

Fig. 2.—Above: Common barley seedlings, eight weeks old, ¼ natural size. Below: Mariout barley seedlings, eight weeks old, ⅓ natural size.

Mariout developes more rapidly both above and below the ground. Note the characteristic onion-like appearance of the Mariout crown; also the more abundant stooling and the earlier and more vigorous development of both the temporary (seed) and the permanent (crown) roots of Mariout.

1919, that it has been under test it has easily maintained a leading rank among dozens of competing varieties, and has especially distinguished itself in drouth years and in spring planting tests (table 5). Illustrative of its suitability for spring sowing, the following instance is representative. The total seasonal rainfall at the University Farm in 1912 was only 9.46 inches. This was the most severe drouth recorded within recent years. On February 2 of that year, field plantings of Mariout and of common barley were made under strictly comparable conditions. Mariout yielded 95.15 bushels (47.57 sacks) per acre, and common barley 41.5 bushels (20.7 sacks) per acre. In a test the same year, planted earlier, Mariout outyielded common barley, but not so decisively as in the late planting test (table 5). This shows the greater advantage of Mariout over common barley for spring planting.

At this juncture, seed for a trial planting of twenty acres was sold to Mr. B. C. French, for a test under actual ranch conditions near Davis, and in this it was at once successful and fully sustained its previous good record on the University Farm. The following year, 1913, Mr. Theodore Oeste, an extensive grain producer of Yolo County, tried it and has continued to produce it in increasingly large quantities to the present time. By degrees other local producers have adopted it, and without exception all have spoken strongly in its praise. To date it has excited more interest among local growers than any other cereal previously introduced by the experiment station, and is each year becoming more firmly established in the opinion of all, as a most valuable and important addition to the productive resources of the county. We feel that it marks an important agricultural advance, and that the benefits to be derived from its wider use in California are of the first magnitude.

In 1917 there were about 300 acres of this barley in California; in 1918, 700 acres; in 1919, 3000 acres; and from present indications the 1920 acreage will exceed 10,000. Yolo County is the center for its production, and all of it originates within a radius of twenty miles of the University Farm (fig. 7).

SPECIFIC QUALITIES OF MARIOUT BARLEY

Drouth Resistance.—Mariout has the rare merit of never succumbing entirely to drouth as common (Coast) barley sometimes does. When hard pressed for moisture, it concentrates all its strength in the formation of heads, and may produce them from six to eight inches above the ground. We have observed such fields, which have given

Fig. 3.—Above: Tennessee Winter barley seedlings, eight weeks old, ¼ natural size. Note heavy stooling, and sturdy, spreading winter habit. In the interior valleys it must be planted early in the fall (November–December) to succeed well. Below: Beldi barley seedlings, eight weeks old, ¼ natural size. It is somewhat more robust as a seedling than common (Coast) barley and slightly more productive under average conditions.

Fig. 4.—Representative heads, of front and side views, of Mariout barley with awns (beards) partly removed to show structure. Mariout heads are stouter, the grains longer and darker, and the outer glumes larger than those of common barley.

Fig. 5.—Representative heads, front and side views, of common (Coast) barley with awns (beards) partly removed to show structure. Below in circle, typical grains, dorsal and ventral views.

the appearance of yielding seven sacks or less per acre, surprise everyone by turning out fifteen sacks per acre. It is suited to high, exposed districts, and to dry soils and seasons. All available experimental evidence from California and other states agree with our opinions in these particulars.

Fig. 6.—Representative plants of Mariout barley (left), and common (Coast) barley (right). Under favorable circumstances Mariout attains a height of 3 feet, compared to 5 feet for common (Coast) barley. Mariout ripens earlier, is more drought resistant, uses less soil moisture, produces a higher percentage of grain to straw, stools more, and yields more and better grain on dry soils.

Suitability to Spring Planting.—Mariout may be spring-sown with much better prospect of success than the bulkier or more tardy common (Coast) barley. It has evidenced high merit with respect to yield on the flood lands of the Sacramento River in Yolo County, where, because of winter inundation, planting must be deferred until the flood waters recede in the spring; plantings made here as late as April 20, have matured in from seventy-five to eighty days and yielded considerably in excess of common barley similarly handled. A signal instance illustrating its peculiar adaptation to spring planting, occurred on the higher lands of Yolo County in 1919, where as a result of

deficient spring rainfall, spring-planted barley was a general faiulre, but not so with Mariout, much of which received no rain whatever subsequent to planting, yet yielded moderately well notwithstanding.

A circumstance, illustrating in a singularly convincing manner the superior drouth resistance of Mariout, is that in late planted fields a sprinkling stand of volunteer common barley often appears simultaneously with the Mariout, but in dry spring seasons like that of 1919, only the Mariout produces seed. This characteristic in itself has enabled growers to maintain their seed, comparatively free from mixture with common barley and much more effectively than would be practicable by any other means.

Draft on Soil Moisture.—Not the least merit of Mariout is its economical use of soil moisture. Determinations made in the Armstrong field at the University Farm immediately after harvest in 1919 showed a saving of moisture by Mariout as compared with common barley, equivalent to 1.27 inches of rainfall in the surface three feet. The results of a large number of determinations made to arrive at this relationship are averaged and condensed for convenience of reference in table 1, which follows.

Table 1.—Soil Moisture Requirements of Mariout and Coast (Common) Barley Compared

	Average inches of rainfall remaining in soil after harvest. June 4, 1919			Average Moisture draft		
Depth	Uncropped check inches	Mariout barley inches	Coast (Common) barley inches	Moisture used by Mariout inches	Moisture used by Coast inches	Moisture saving in favor of Mariout, inches
1st foot	1.90	1.17	1.04	.73	.86	.13
2nd foot	2.21	2.14	1.02	.07	1.19	1.12
3rd foot	2.33	1.44	1.42	.89	.91	.02
Total	6.44	4.75	3.48	1.69	2.96	1.27

Of a total supply of moisture equivalent to 6.44 inches of rainfall remaining in the fallowed check, common barley had reduced this to 3.48 inches, and Mariout to 4.75 inches; the comparative moisture drafts were therefore 2.96 inches, or 45 per cent, and 1.69 inches, or 26 per cent, respectively.

This striking difference in the use of soil moisture is of the greatest practical importance, and must be accounted the most significant reason for the well-known drouth resistance of the variety. The saving of an inch or more of rain in a dry season might well determine the success or failure of a crop, and under continuous cropping the cumulative effect of such saving over a period of years would be still

greater. For these reasons, there is little doubt that many of the dry soils which we see carrying scanty crops of common barley would give a more remunerative return if sown to Mariout.

The direct effect of Mariout's lighter moisture draft is always apparent in the growth of weeds, which because of the greater moisture supply remaining, grow taller and continue green later in Mariout fields than in common barley fields.

Wind Resistance.—The weightiest consideration in the choice of either a wheat or barley variety for the interior valleys of California is resistance to wind, and the ability to stand up in the field and hold its grain retentively in the head without shattering or shelling out after ripening. The almost exclusive use of the combined harvester necessitates the employment of such varieties. Club wheat has taken precedence over all other wheats in California for many years, for no other reason than that it does not shatter during the strong harvest winds, and consequently does not have to be cut early to avoid hulling. Barley is more brittle and suffers greater wind damage than wheat. A strong north wind of three days' duration swept the Sacramento Valley on May 30, 31, and June 1, 1919, at the very start of the harvest season, and resulted in a loss of fully 25 per cent of the entire barley crop of the valley. The Mariout fields of Yolo County, however, proved an exception, and withstood the wind in a manner precisely analogous to that of the well known Club wheat (table 2). This characteristic is in itself a strong recommendation for this variety in the interior valleys of California.

Immediately following harvest on the University Farm in 1919, a critical examination of the stubble fields was made, and the exact shattering losses for both common and Mariout barley accurately determined. Both fields were planted November 9; Mariout ripened May 15, common barley June 6; both were cut with the combined harvester, June 17 (fig. 24). Mariout stood for thirty-three days after ripening; common for eleven days. Both varieties were exposed to the strong north wind of May 30, 31, and June 1, and if Mariout had been cut when ripe, it would have escaped the wind entirely. Mariout yielded 39.5 sacks (79 bu.) per acre, and common barley 19 sacks (38 bu.) per acre, but practically as much grain was left on the ground in the common field as was put in the sacks, and the difference in yield is more indicative of the relative resistance to shattering than of the actual production of the two varieties. The harvesting, however, was done strictly in accordance with commonly employed methods, and it is a fair indication of what may be expected from the

two varieties under existing conditions. Indeed, many fields of common barley, less protected from the wind, in the neighborhood were so completely "whipped out" as not to repay the expense of cutting them.

The actual shattering losses were determined by picking up by hand all heads and grain remaining on the ground in accurately measured plots, three of which were chosen for each field. The average results are compiled in table 2.

TABLE 2.—ACTUAL YIELD, ACTUAL SHATTERING LOSS, AND TOTAL POSSIBLE YIELD FOR MARIOUT AND COAST (COMMON) BARLEY AT THE UNIVERSITY FARM IN 1919

Variety	Area of test acres	Actual yield per acre		Actual shattering loss per acre		Total possible yield per acre		Per cent. of loss through shattering
		Bushels	Sacks	Bushels	Sacks	Bushels	Sacks	
[1]Mariout	9.01	79	(39.5)	10.81	(5.4)	89.81	(44.9)	12
Common (Coast)	2.84	38	(19.0)	33.2	(16.6)	71.2	(35.6)	46

[1] Duplicate 4.5 acre plots.

The loss for Mariout was 10.81 bushels (5.4 sacks) per acre, and for Coast barley 33.2 bushels (16.6 sacks) per acre. Mariout doubled common barley in yield for the reason that it lost only one-third as much through shattering, but had both varieties been cut with the binder "in the dough" (fig. 22), and shattering losses eliminated entirely, Mariout would still have outyielded common by 18.6 bushels (9.3 sacks) per acre, and had the period of exposure to the weather after ripening been equal, the advantage of Mariout would doubtless have been still greater.

There are two reasons why Mariout is resistant to shattering. First, its more pliable straw (fig. 6), causes the heads to nod at maturity in such a manner that they hang in a mat about 14 inches above the ground, protected from the wind. Secondly, the heads of Mariout are stouter and more compact (figs. 4 and 5), and even late plantings, which stand more erectly, do not shatter as much as the more slender heads of common barley.

Special Fitness for the Tulare Lake Region.—Extensive losses have occurred in the Tulare Lake and Kings River grain districts as a result of floods before and during the regular harvest season (fig. 9). The vital consideration here is to advance the harvest date as far as possible ahead of the earliest high water. Mariout is climatically well suited to this region, and by virtue of its earlier ripening (table 4) its wider use is recommended as a means of escaping flood losses.

Special Fitness for Double Cropping.—In the irrigated districts of the San Joaquin Valley, the growing of a summer crop, such as beans or grain sorghum after grain harvest has become popular (fig. 21). The usual procedure is to irrigate and plant grain from September 25 to November 5, to harvest the same from May 15 to June 15, and to irrigate and plant beans or grain sorghum from May 25 to June 25; harvesting the same from September 15 to October 25, in time to replant to grain from September 25 to November 25. By such a system the land yields two crops in a twelve-month cycle, but quick-maturing, short-season varieties are necessary. Mariout offers a considerable advantage over the common barley for such purposes because it shortens the winter crop season by about two weeks.

Hay Values.—A character of minor importance, yet one not to be overlooked in this region, is the utility of a grain variety for hay-making purposes. Barley in its many variety is inferior to either oats or wheat as a hay crop, both from the standpoint of yield and feeding value. At the University Farm common barley has yielded only 4.51 tons of cured hay per acre, compared with 6.43 and 7.05 tons per acre for red oats and Pacific Bluestem (White Australian) wheat, respectively. Mariout is even less productive as a hay crop than common barley, and has, on an average, produced 15 per cent less hay. Mariout hay, however, is finer and more palatable than common barley hay, and the plant has the property of making considerably more second growth than common barley, especially if cut in the "blossom" or early milk. In this respect it resembles rye more than any of the other barley varieties tested, and must owe this property in some degree to its lighter moisture requirement.

Limitations and Defects.—Mariout is a more generally satisfactory variety for California than common (Coast) barley, but its most serious limitation is its inability to produce well in the cooler northern districts and on heavy low-lying soils, which are wet for long periods during the winter. The variety "Tennessee Winter" (fig. 3) succeeds better than either the Mariout or common barley in such situations. Its second defect is its dwarf stature, which in very dry situations precludes the use of the binder as a harvesting implement, but never the "combine" or the header.

A third, and somewhat doubtful objection to it is its effect upon weed growth. As previously suggested, its short stature, coupled with its early ripening and lighter moisture draft, gives the weeds a greater opportunity to develop, sometimes at the expense of grain production. This is especially apparent on foul land which is fall

planted without a preceding summer fallow to free it of weeds. Two instances of this came under the writer's attention during the season of 1919. One field, badly infested with mustard (*Brassica campestris*), was divided into two parts which were sown to common and Mariout barley, respectively. The weeds in the "Mariout half" formed a canopy over the grain and grew tall and late in the season, while those in the "common half" matured earlier and did not dominate the grain so completely. The difference here is directly attributed to the greater supply of soil moisture remaining in the Mariout ground (table 1).

Fig. 7.—Common (Coast) barley (left), and Mariout barley (right), planted in December and photographed in March. Note the upright habit, and the earlier and mare vigorous spring growth of Mariout. In dry spring seasons, Mariout shades the ground sooner, preventing crusting and drying of the soil, and by virtue of its earlier ripening, is less dependent upon spring showers to carry it to maturity.

DETAILED DESCRIPTION OF MARIOUT

Seedling Development.—The early development of Mariout is very rapid (fig. 2). Plants eight weeks old average twelve inches in height, compared to seven inches for common barley (fig. 8). Mariout shades the ground sooner and thereby stops evaporation earlier in the spring; a circumstance contributing to its value for spring seeding (fig. 8). Mariout maintains its lead in height growth until about the sixteenth week, when it passes rapidly through "booting," "heading," "blossoming," and "ripening" without further height development. Common barley, on the other hand, starts slowly, and does not overtake Mariout until about the sixteenth week, and not stopping then, continues to develop in height for three weeks more, attaining ultimately, under favorable conditions, a total height of five feet compared to

three feet for Mariout (fig. 6). From the standpoint of harvesting with the "combine" the shorter straw of Mariout is generally regarded as an advantage.

Life Period.—Under average circumstances fall-planted Mariout requires about 152 days to ripen; and spring-planted requires from eighty to ninety days. Coast barley under similar circumstances requires from ten to twenty days longer. Earliness is an essential barley characteristic in all dry climates, including the interior valleys of California, since it enables the plant to mature with a smaller and less generally distributed rainfall. Such is the case wherever dry-

Fig. 8.—Pure strains of Mariout (left), and common barley (right), in the increase nursery at the University Farm. Mariout frequently escapes wind damage because of its earlier ripening, and always resists wind because of its habit of growth. These plantings were made November 13, 1918; Mariout ripened May 16, 1919, and common barley ripened fifteen days later, on May 31. Mariout entirely escaped the strong north wind of May 31, while the common barley was exposed to it and shattered badly.

farmed barley is produced, and the other cereals are obedient to the same law.

Physical Analysis of Mariout.—Mariout is a smaller and less bulky plant than common barley and yields a higher percentage of grain with a correspondingly lower percentage of straw. It also yields a higher percentage of leaf to stalk, as is shown by the following physical analysis of representative plants (fig. 6).

TABLE 3.—PHYSICAL ANALYSIS OF MARIOUT AND COMMON BARLEY

	Mariout per cent.	Common per cent.
Heads including grain, awns, and rachis	57.58	43.94
Straw cut at first node above root and immediately below head	30.77	37.57
Leaves	6.08	5.64
Stubble with roots as pulled	5.57	12.85

Field Characteristics.—Mariout differs from common barley in various minor particulars; although individual plants may show some variations, the two varieties as a whole, may be roughly separated upon the following points of difference.

TABLE 4.—MINOR PARTICULARS IN WHICH MARIOUT DIFFERS FROM COMMON BARLEY

	Mariout	Common
Average number days to ripen (fall planted)	152	162
Average number days to ripen (spring planted)	85	100
Average number tillers per plant, drilled 80 lb. per A	9	6
Average number joints per stalk	7	8
Average length of internodes in inches	5	7
Average length of leaf in c.m	10.5	12
Average width of leaf in c.m	1.9	1.7
Average number permanent roots 50 days old (fig. 2)	4	2
Average number temporary roots 50 days old (fig. 2)	6	5
Average length of head inches	3	3.5
Average number grains per spike	66	84
Shape of spike	oblong	fusiform
Average length grain in mm	14	12
Average width grain in mm	4	4
Color grain	yellow brown	straw
Rachilla	bristly	smooth

YIELD RECORD AT DAVIS, CALIFORNIA

During the nine seasons, 1911 to 1919, that Mariout has been grown under field conditions at the University Farm it has withstood the closest scrutiny and the severest tests in a manner which can leave no doubt as to its superiority over common or Coast barley at this place. Each season, several plantings have been made, so that the figures given in table 5 represent in most cases average yields from replicated plots. The tests have been conducted on a deep, rich, "Yolo fine sandy loam" soil, and deep-plowing, summer-fallowing, fall-drilling, and other improved culture practices, discussed under "Tillage Methods," have been employed. Consequently, the reported yields are somewhat higher than those generally obtained in the community. The yields are reported in both bushels and sacks per acre. The sack is approximately equivalent to two bushels.

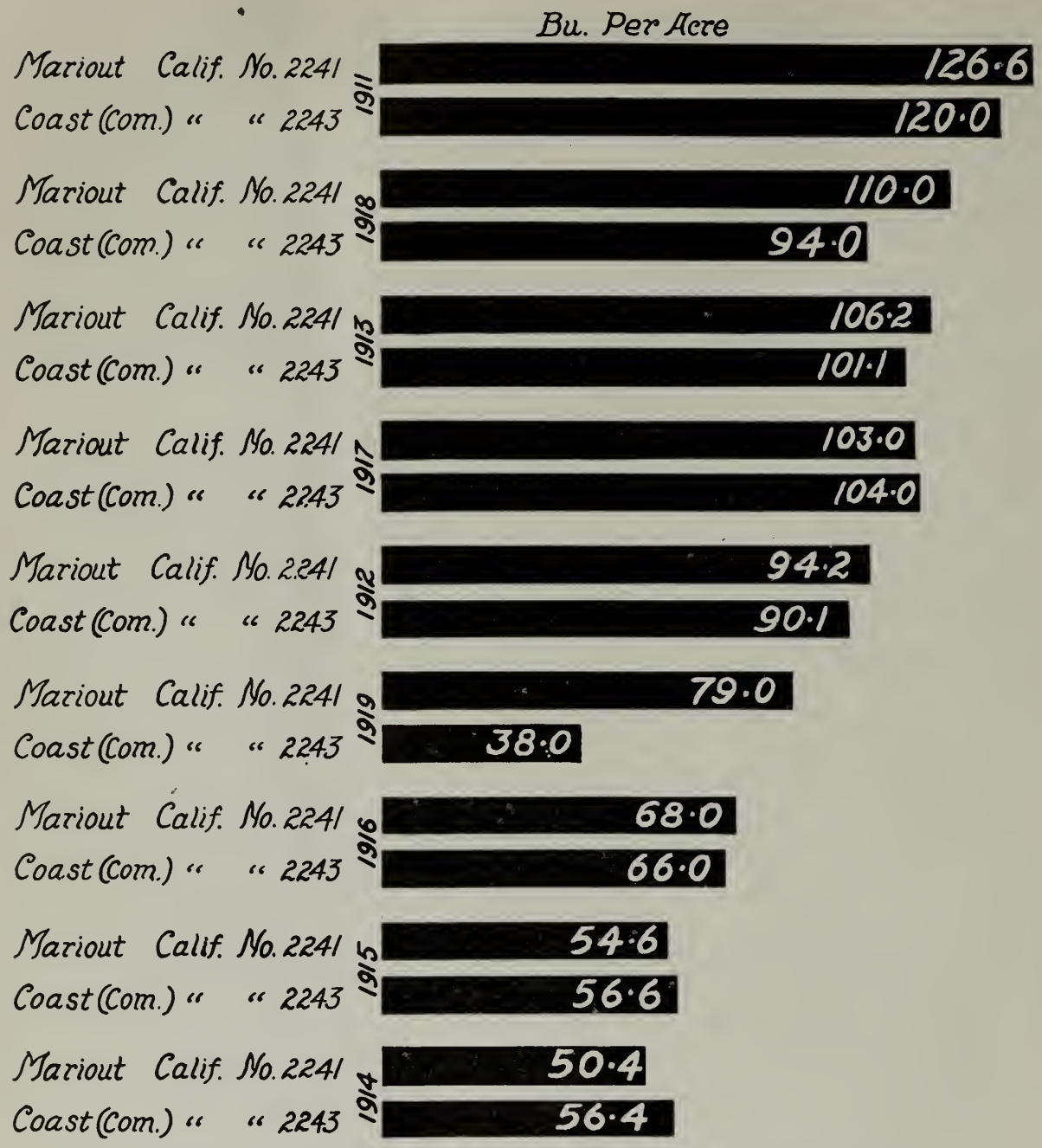

Fig. 9.—Diagram showing the relative yields of Mariout barley, Calif. no. 2241, and Coast (common) barley, Calif. no. 2243, from 1911 to 1919 inclusive at the University Farm, Davis, Calif.

TABLE 5.—YIELD OF MARIOUT AND COAST (COMMON) BARLEY IN BUSHELS AND SACKS PER ACRE AT THE UNIVERSITY FARM, DAVIS, CALIF.

Year	Mariout (Calif. No. 2241) Bushels	Mariout (Calif. No. 2241) Sacks	Common (Coast) (Calif. No. 2243) Bushels	Common (Coast) (Calif. No. 2243) Sacks
1911	126.6	(63.3)	120.0	(60.0)
1912	94.2	(47.1)	90.1	(45.05)
1913	106.2	(53.1)	101.1	(50.05)
1914	50.4	(25.2)	56.4	(28.2)
1915	54.6	(27.3)	56.6	(28.3)
1916	68.0	(34.0)	66.0	(33.0)
1917	103.0	(51.5)	104.0	(52.0)
1918	110.0	(55.0)	94.0	(47.0)
1919	*79.0	(39.5)	38.0	(19.0)
Average	88.0	(44.0)	80.68	(40.34)

* Average of duplicate 4.5 acre plots.

These figures, instructive as they stand, are of still greater significance when interpreted in connection with seasonal variations, since they then emphasis the fact that Mariout is somewhat more productive under average conditions, and decisively more productive under dry conditions, than common barley at the University Farm. Apart from the fact that Mariout has averaged 7.32 bushels or 3.66 sacks more per acre than common barley, there are several things of minor interest brought out. In the years 1918 and 1919, Mariout has been outstandingly superior; and as 1918 was a drouth year with a total seasonal rainfall of only 9.66 inches, and 1919 was a year of markedly deficient spring rains, the peculiar fitness of Mariout to such conditions becomes apparent.

It is, moreover, important to remember that in all of these tests, early fall planting (November and December) was practiced, and consequently conditions were comparatively more favorable to the common barley than to Mariout. In tests comparing the two varieties with spring planting (February and March), the yield differential has been much more decisively in favor of Mariout. A case in point is taken from the 1912 records. In that year Mariout, planted late (February 2), yielded 95.15 bushels (47.57 sacks) per acre and common barley planted at the same time yielded 41.5 bushels (20.75 sacks per acre, giving a differential of 53.65 bushels (26.82 sacks) per acre in favor of Mariout. In the earlier planting the same year, quoted in table 5, the differential was only 4.1 bushels (2.05 sacks) in favor af Mariout. It is also interesting to note that the yield of Mariout was actually higher in the late than in the earlier plantings, while the yield of common barley was diminished by one-half as a consequence of late planting.

A further interesting and significant observation is that in the two seasons, 1914 and 1915, common barley slightly exceeded Mariout in yield; also, that in these two years both varieties fell considerably below the general average in yield. The contributing cause in these cases was the excessively cold wet winter seasons; the total seasonal rainfall in 1914 was 28.7 inches and in 1915, 20.05 inches, and while both varieties are affected injuriously under such circumstances, common barley is slightly better able to cope with them than is Mariout. Tennessee Winter barley (fig. 3), on the other hand, withstood the cold, wet soil conditions better than either the common or Mariout and yielded higher than either, with 67.6 bushels (33.8 sacks) in 1914 and 63.9 bushels (31.9 sacks) in 1915.

Summing up fifteen years of experiments with these two varieties in California, Mariout has proved to be slightly more productive than common barley under average conditions, and decidedly more productive both in dry years and when spring-sown.

YIELD RECORDS IN OTHER PARTS OF CALIFORNIA

Mariout has been grown at the various California sub-stations both to the north and south of Davis. At the Imperial Valley sub-station, under arid conditions, it has made a favorable impression and has given the appearance of producing more heavily than the common variety. At the Kearney Park sub-station, in Fresno County, representative of the south San Joaquin Valley, it has also been favorably reported upon, and appears to be more productive than the common barley there.

It has been grown for four years at the United States Plant Introduction Garden at Chico, representative of the north Sacramento Valley, and while its performance record in this more northern climate has not been so outstandingly superior to that of the common barley as in other drier parts of the state, it has averaged 4.6 bushels (2.3 sacks) per acre above it, and in the dry spring of 1919 exceeded it by 21.6 bushels (10.8 sacks) per acre.

We are indebted to Mr. V. H. Florell, of the Plant Introduction Garden, for the data in table 6.

Table 6.—Yields of Mariout and Common (Coast) Barley, in Bushels and Sacks per Acre, at the Plant Introduction Garden, Chico, Calif.

Year	Mariout		Coast (Common)	
	Bushels	Sacks	Bushels	Sacks
1916	66.6	(33.3)	64.8	(32.4)
1917	50.6	(25.3)	54.1	(27.05)
1918	61.8	(30.9)	63.4	(31.7)
1919	58.6	(29.3)	37.0	(18.5)
Average	59.4	(29.7)	54.8	(27.4)

In the Livermore Valley, Mr. T. E. Rice has grown Mariout experimentally, and reports that in poor years it has been more productive than the common variety.

YIELD RECORD AT HIGHMORE, SOUTH DAKOTA

Mariout has also been grown in several other western experiment stations in competition with established varieties, and while it has not in all cases shown to such an advantage as in California, it has invariably proved its special aptitude to droughty localities and short, hot seasons.

At the United States Department of Agriculture substation at Highmore, in east central South Dakota, under semi-arid climatic conditions, with an average seasonal rainfall of 12.24 inches, and frequently recurring hot south winds during the growing season, it has made the following record in competition with Coast (common) barley and "Odessa," which is regarded as the best variety for that locality. The data in table 7 is reported by Mr. E. S. McFadden of the Highmore substation.

TABLE 7.—YIELDS OF MARIOUT, COAST (COMMON), AND ODESSA BARLEY, IN BUSHELS AND SACKS PER ACRE, AT THE HIGHMORE SUB-STATION, S.D.

Year	Mariout		Coast (Commn)		Odessa	
	Bushels	Sacks	Bushels	Sacks	Bushels	Sacks
1910	15.6	(7.8)	8.3	(4.15)	7.5	(3.75)
1911*	.....	.....	.....	.....	.....	.....
1912	5.5	(2.75)	3.9	(1.95)	2.1	(1.05)
1913	4.8	(2.4)	7.3	(3.65)	6.9	(3.45)
1914	36.4	(18.2)	44.8	(22.4)	47.9	(23.95)
1915	49.9	(24.95)	79.0	(39.5)	79.0	(39.5)
Average	22.44	(11.22)	28.6	(14.3)	28.68	(14.34)

*All crops destroyed by hail.

In seasons of good rainfall all varieties have yielded moderately well, but the significant feature of these tests has been the greater productiveness of Mariout in the drouth years. In 1910 the total seasonal rainfall (April 1 to August 31) was only 7.59 inches, and as a consequence, Mariout practically doubled the other two varieties in yield. Again in 1912 the total seasonal rainfall was only 9.39 inches, and as in the 1910 test, Mariout again demonstrated its superiority.

YIELD RECORD AT MOCCASIN, MONTANA

Mariout has been grown for nine years at the United States Department of Agriculture Field Station at Moccasin, Montana. The average seasonal rainfall there (April 1 to July 1) has been 9.41 inches, and the drouth years occurring during the period of the experiment have given an excellent opportunity to compare Mariout with the common variety in dry seasons, as well as in seasons of normal rainfall. We are indebted to Mr. W. P. Baird, of the Judith Basin Station, for the data in table 8.

The fact that Mariout has yielded on the average for the nine-year period, 3.27 bushels (1.63 sacks) per acre above common barley is of small consequence compared with the finding that it has regularly exceeded common barley in the dry seasons. The years 1910 and 1911 were drouth years, with total seasonal rainfalls of 6.5 and 7.69 inches,

respectively, and in both tests Mariout outyielded common (Coast) barley. In the years of normal rainfall Mariout has occasionally been exceeded in yield by common barley.

TABLE 8.—YIELDS OF MARIOUT AND COAST (COMMON) BARLEY IN BUSHELS AND SACKS PER ACRE AT THE JUDITH BASIN FIELD STATION, MOCCASIN, MONTANA

Year	Mariout		Coast (Common)	
	Bushels	Sacks	Bushels	Sacks
1910	16.2	(8.1)	15.0	(7.5)
1911	47.0	(23.5)	43.7	(21.85)
1912*	.....	.....	.....	.....
1913	47.9	(23.95)	55.0	(27.5)
1914	51.3	(25.65)	43.1	(21.55)
1915	72.0	(36.0)	83.1	(41.55)
1916	32.8	(16.4)	32.0	(16.0)
1917	15.2	(7.6)	14.6	(7.3)
1918	35.1	(17.55)	39.0	(19.5)
Average	39.44	(19.72)	36.17	(18.08)

*Crops destroyed by hail.

YIELD RECORD AT MORO, OREGON

Mariout has been grown at the United States Department of Agriculture eastern Oregon dry-farm field station for eight years with the extremely low average total annual precipitation of 11.6 inches, and in competition with twenty-eight other barley varieties has maintained the highest average yield for the period. We are indebted to Mr. D. E. Stephens of Moro, Oregon, for the following figures.

TABLE 9.—YIELDS OF MARIOUT AND COAST (COMMON) BARLEY IN BUSHELS AND SACKS PER ACRE, AT THE U.S.D.A. EASTERN OREGON DRY-FARM STATION, AT MORO

Year	Mariout		Coast (Common)	
	Bushels	Sacks	Bushels	Sacks
1911	6.3	(3.15)	2.9	(1.45)
1912	28.0	(14.0)	23.3	(11.65)
1913	40.6	(20.3)	38.3	(19.15)
1914	42.1	(21.05)	32.5	(16.25)
1915	54.5	(27.25)	51.2	(25.6)
1916	69.3	(34.65)	72.5	(36.25)
1917	45.4	(22.7)	36.5	(18.25)
1918	29.0	(14.5)	20.4	(10.2)
Average	46.9	(23.45)	37.2	(18.6)

Mariout has been a pronounced success in the dry climate of Moro, Oregon, where it has averaged 9.71 bushels (4.85 sacks) per acre above the common (Coast) variety, and has exceeded it in yield seven out of the eight years that it has been grown there.

YIELD RECORD AT ABERDEEN, IDAHO

Mariout and common (Coast) barley, together with numerous others, were grown at the Idaho Agricultural Experiment Station for three years, both with and without irrigation, and the general conclusion was reached that the varieties Mariout and Smyrna were the best tested for dry land, and Trebi the best for irrigated land. We are intebted to Mr. L. C. Aicher, of the Aberdeen substation, for the figures in table 10.

TABLE 10.—YIELDS OF MARIOUT AND COAST (COMMON) BARLEY ON DRY LAND, IN BUSHELS AND SACKS PER ACRE, AT THE IDAHO AGRICULTURAL EXPERIMENT STATION, ABERDEEN, IDAHO.

Year	Mariout		Common (Coast)	
	Bushels	Sacks	Bushels	Sacks
1913	43.8	(21.9)	28.3	(14.15)
1914	35.5	(17.75)	38.1	(19.05)
1915	13.3	(6.65)	10.1	(5.05)
Average	30.86	(15.43)	25.5	(12.75)

YIELD RECORD AT BURNS, OREGON

Mariout and common (Coast) barley have also been grown at the United States Department of Agriculture Harney County Branch Station at Burns in central Oregon for five years, where the average annual rainfall is 11 inches, and where summer frosts during the growing season are of frequent occurrence. We are indebted to Mr. O. Shattuck, superintendent of the station, for the following figures.

TABLE 11.—YIELDS OF MARIOUT AND COAST (COMMON) BARLEY, IN BUSHELS AND SACKS PER ACRE, AT THE U.S.D.A. HARNEY COUNTY SUB-STATION, BURNS, OREGON.

Year	Mariout		Common (Coast)	
	Bushels	Sacks	Bushels	Sacks
1913	19.0	(9.5)	31.5	(15.75)
1914	19.6	(9.8)	15.6	(7.8)
1915	14.3	(7.15)	13.4	(6.7)
1916	35.2	(17.6)	45.4	(22.7)
1917	9.2	(4.6)	13.8	(6.9)
Average	19.46	(9.73)	23.94	(11.97)

In these tests at Burns, Oregon, Mariout has been inferior to common barley in point of yield. The average daily mean temperature at this station is from 2 to 10 degrees lower than that of the other grain regions of the northwest, and summer frosts occur frequently during the growing season in June, July, and August. Knowing the sensitiveness of Mariout to such conditions in California, the yield

data confirms our opinion, that Mariout is less desirable than the common variety in the cool mountainous districts.

Reviewing the yield data from seven western experiment stations, it is found that Mariout has exceeded common (Coast) barley in point of yield at five of them, and has outyielded common barley most decisively in dry seasons and in hot arid climates.

MALTING PROPERTIES

In the past, malsters have required the best quality barley grown, and have paid the highest prices for it. Consequently barley grades and prices have been chiefly determined by suitability to malting purposes. California barley, known to the trade as Bay Brewing, but in reality only a grade of the "Coast" or "common" variety, has generally been regarded as superior to the eastern varieties of the same type for malting purposes, and in view of the growing importance of Mariout in California, apprehension has been felt in some quarters that it might not equal the common variety for malting. Recent tests, however, have shown that no distinction can be drawn between them in this respect. Through the courtesy of the E. Clemens Horst Company of San Francisco these two varieties have been submitted to the leading malsters throughout the United States, and definite malting values have been assigned them through these agencies.

The Wahl-Henius Institute of Fermentology, Chicago, Illinois, reports as follows:

Variety: Mariout Barley.
Crop: 1916.
Grown by: University of California, Agri. Exp. Farm, Davis.
Variety and Admixture: Six-rowed Barley.
Color and brightness: Pale straw to yellow. Slightly stained. Fairly bright.
Odor: Good.
Thickness of husk: Average.
General Impression: Fairly regular in size and form. Poorly threshed. Slightly immature.

Offal	By screen:	1.1 %	4.8%
	By water:	0.07%	
	By blower:	0.05%	
	By cockle-machine	3.6 %	
Sprouters			0.0%
Remaining foreign substances			0.0%

Variety: (Coast) Barley.
Crop: 1916.
Grown by: University of California, Agri. Exp. Farm, Davis.
Variety and Admixture: Six-rowed Barley.
Color and brightness: Pale straw to yellow mixed. Slightly stained. Fairly bright.
Odor: Good.
Thickness of husk: Slightly below ave.
General Impression: Fairly uniform in size and form. Insufficiently threshed. Slightly immature.

Offal	By screen:	1.7 %	4.7%
	By water	0.2 %	
	By blower:	0.05%	
	By cockle-machine	2.7 %	
Sprouters			0.0%
Remaining foreign substances			0.0%

Merchants' or Graders' Test, Ave.—
1000 berryweight.....41.4 grams
Uniformity as to size.....88.7%
Germinating capacity.....98.2%
Moisture..... 9.5%

Maltsters' Tests, Ave.—
Albumen (Nx6.25)..... 12.2%
Uniformity as to variety: very good (by botanical examination).

Bottle Beer Brewers' Tests, Ave.—
The available barley for malting in this sample is (100—% Offal)..... 95.2%

Merchants' or Graders' Test, Ave.—
1000 berryweight.....42.2 grams
Uniformity as to size.....89.8%
Germinating capacity....98.8%
Moisture..... 9.6%

Maltster's Tests, Ave.—
Albumen (Nx6.25)..... 12.3%
Uniformity as to variety: very good (by botanical examination).

Bottle Beer Brewers' Tests, Ave.—
The available barley for malting in this sample is (100—% Offal)..... 95.3%

Signed:

WAHL-HENIUS INSTITUTE.

They conclude that both are equally capable of making good malting grades. The Schlitz Brewing Company, of Milwaukee, reports as follows:

PHYSICAL EXAMINATION

	Mariout	Common (Coast)
Appearance	not very uniform	not very uniform
Color	pale yellow	light yellow
Gloss	dull	dull
Consistency of hull	thick and coarse	thick and coarse
Purity	very good	very good
Grading: 7.64 in	43.8 %	45 %
5 1–12 –64 in	53.0 %	54 %
3–63 in	3.2 %	1 %
	100.0 %	100 %
Germination	good	good
Taste	normal	normal
Odor	normal	normal
Consistency of mealy body	flinty	flinty
Shape of kernels	full-bodied	full-bodied
Weight of 1000 kernels (dry substance)	50.3 grams	53.0 grams
Swimmers	2 %	1 %
Germination test: Filter paper method 500 kernels:		
Growth after 48 hours	93.8 %	67.8 %
Growth after 72 hours	97.0 %	94.7 %
Growth after 96 hours	97.6 %	98.5 %
Germination energy	very good	very good
Germination capacity	very good	very good

CHEMICAL EXAMINATION

	Mariout	Common (Coast)
Moisture	9.78 %	9.60 %
Protein	11.38 %	11.99 %
Protein (dry sub.)	12.61 %	13.26 %

Signed:

JOS. SCHLITZ BREWING CO.

The company concludes that both varieties are very similar in quality.

TILLAGE METHODS

Experiments at the University Farm have clearly demonstrated several fundamentally important things relating to the most economic methods of grain production, and while of necessity much of the investigational work with crops conducted at the Farm is of a special character, and chiefly valuable in its application where similar conditions exist, we may nevertheless derive from it many points which have a general bearing and well illustrate the principle which we wish to inculcate.

Annual or Biennial Cropping.—The question of whether it is more profitable to crop land to grain continuously every year, or to summer fallow it during alternate years is frequently an important and difficult one to decide, especially in districts in the borderland between the regions of ample and deficient precipitation. A conclusion which has been reached in studying this question at the University Farm over a period of several years, during which both systems have been practiced, and the costs of production and net profits per acre correlated with fluctuating seasonal rainfall, is, that biennal cropping should be practiced in those districts where the average seasonal rainfall is less than 16 inches, and annual cropping should be practiced where the seasonal rainfal is above 18 inches. Where the average seasonal rainfall is from 16 to 18 inches there is little choice from a money viewpoint, but the introduction of a fallow every third or fourth year would probably have a salutary effect upon the land. Much of the success of either system, of course, depends chiefly upon the manner and time of working the land, and in the following paragraphs the important principles of land preparation and its relations to dry-land grain farming in California are discussed.

Disking the Stubble.—Independent of whether annual or biennial cropping is practiced, it is advisable to disk the stubble soon after harvest, using preferably a double cut-away disk, weighted and set for deep penetration. Such an implement may well be attached directly behind the combined harvester, and the first step in the

preparation of the land for the succeeding crop accomplished simultaneously with the harvesting of the preceding crop. Such treatment not only prepares the ground for easier and smoother plowing, but it checks evaporation and collects residual moisture near the surface, so that the land many be plowed at an earlier date. Moreover, it encourages the earlier growth of weed seeds, and is especially recommended for land producing grain annually. The actual saving of moisture by this treatment often amounts to an equivalent of 2½ inches of rain to a depth of six feet.

Fall Plowing.—Land devoted to the production of grain should be plowed deeply, eight to ten inches, at the earliest date in the fall when it is in good working condition. Plowing dry prior to the rainy season is of doubtful advantage (fig. 17), excepting on the lighter soil types, and in conjunction with annual cropping. An extended series of experiments at the University Farm, comparing deep (eight-inch) fall plowing with shallow (four-inch) fall plowing, has shown that the yield of barley may, on an average, be increased 7 bushels (3½ sacks) per acre, by the deeper plowing, provided it is done early in the fall. The winter rainfall in California is intermittent and at times torrential, so that deep soil preparation is necessary to catch it and prevent losses through surface drainage. Moreover, the principal root feeding area of cereal crops is largely limited to the depth of soil turned by the plow; and the increased feeding area provided by deeper plowing is an important aid in increasing yields, especially where the rainfall is light, and the surface soil drys rapidly in the spring, leaving the plants on shallow-prepared land stranded in the early stages of development, and without adequate connection with the deeper supplies of moisture. But a caution is necessary here. We must not regard it as certain in every case, or indeed in most cases, that yields may be increased 7 bushels (3½ sacks) per acre by merely deeper plowing. Under certain circumstances shallow plowing yields better results than deep plowing, and the underlying reason for this is again a question of moisture conservation. Spring-plowed land, being drier, does not settle readily, and generally dries quickly to the depth plowed; consequently, shallow spring-plowed land loses less moisture than deep spring-plowed land, and in dry years naturally yields more. Moreover, deep *spring* plowing is undesirable from the standpoint of seed-bed preparation. Freshly plowed land is never a suitable medium for the seeding of small grains; to secure the best results a period of several weeks, with considerable rain, should intervene between deep plowing and planting, in order to obtain a firm

texture and to obliterate air spaces in the lower seed-bed zone. Shallow spring plowing, on the other hand, merely loosens the surface, leaving a firm moist stratum directly beneath, and provides better conditions for plant growth in the late winter or early spring.

For these reason shallow spring plowing has given higher grain yields at the University Farm than deep spring plowing. Many grain farmers in the Sacramento Valley prepare land for planting by one plowing only, viz., late in the season (January to February), in order to destroy weeds and fit the land for planting at a single operation. This single late plowing is generally a shallow one, since it has been learned from experience that deep spring preparation is detrimental to the crop.

The system of producing grain by a single plowing, however, is at best a negligent and unprofitable one, for the reason that no error could be more certainly fatal to the success of the crop than the combination of late seeding and shallow seed-bed preparation which it entails. The most desirable preparation, where annual cropping is practiced, consists of a deep (ten-inch) plowing early in November, followed by a shallow plowing, disking and harrowing a few weeks hence. Such double working will combine the advantages of deep plowing and deep rooting, with a firm, clean, well consolidated seed bed.

How to Summer-Fallow.—Judging from the summer-fallow methods in vogue over a large part of the dry-farmed grain districts of California, it is evident that there is a general misapprehension of the principles of moisture conservation. The steps in the preparation of the fallow should be as follows: first commence with the disking of the stubble immediately after harvest; second, deep plowing of the land during November or December; and third, allow the land to lie rough in the furrow as turned by the plow, throughout the rainy season, for in this condition it will absorb more rain and be benefited by its exposure to the weather. By spring the plowed ground will have settled well and the fallow may be prepared by a shallow plowing to destroy weeds or, if the land is clean, a cultivation or harrowing may answer equally well. The aim should be to establish the mulch before the surface has become hard and crusted, and to do it at such times and in such manner that a coarsely granular structure may be given (fig. 15). If rain occurs after its establishment, send in the harrows again and break the crust at the right moment. It is preferable to do this several times, rather than to defer it until the ground is too dry and hard to be worked effectively.

Popular opinion has favored leaving the land in the stubble throughout the winter, and preparing the fallow by dry plowing from May to July (fig. 17), but such fallowing is very wasteful of moisture, and has nothing to recommend it, excepting that it offers the course of least resistance. Still others have adhered to the practice of simply resting the land for a year, by pasturing the stubble throughout the winter and summer seasons following harvest. This system offers the advantage of manuring the land, and is justifiable in localities of

Fig. 10.—A deep working chisel cultivator stirring the ground to a depth of seven inches. Treatment of this character improves a fallow which has developed a "sole" by too frequent weed cutting; and is efficient in disintegrating plow soles at a season of the year when deep plowing would be inadvisable from the standpoint of moisture conservation.

abundant rainfall, but is inconsistent with dry-farming principles, and in the drier districts is even less defensible than the summer-plowing system outlined above.

The ideal summer fallow is prepared as outlined by a combination of deep fall plowing and shallow spring working. The soil should go into the dry summer months protected by a granular mulch three or four inches in depth. Choose the implement for the spring working which will granulate the surface to a texture comparable in size with English walnuts (fig. 15). Use the disk with caution, for it may

pulverize the soil too finely, causing "running together," crusting, and baking, subsequent to planting.

Care of the Fallow.—The proper establishment of the summer fallow is a more exacting process than its subsequent treatment. This applies especially to the California grain districts where summer rains do not occur. California grain lands, however, are generally speaking, uncommonly weedy, and an occasional summer working of the fallow to clean it is, in most cases, necessary to secure the best results. A weedy fallow is objectionable on three scores: first, it

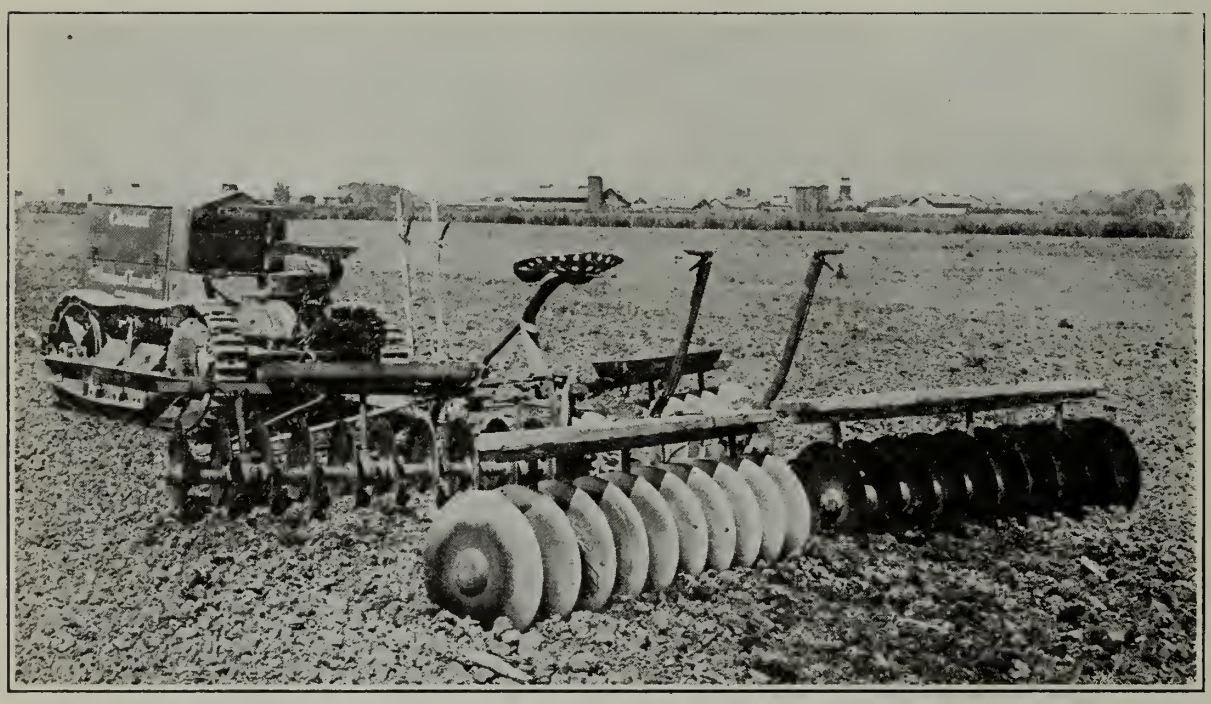

Fig. 11.—A disk-prepared summer fallow at the University Farm. The texture of the soil mulch shown here is regarded as ideal. It is neither coarse and refractory, nor is it so finely pulverized that there is danger of its "running together" and crusting when rained subsequent to planting. The disk harrow is less effective for weeding the fallow than the sweep type weed cutter (fig. 12), and its continued use on the fallow may pulverize the soil too finely.

does not conserve moisture effectively; second, it necessitates replowing preparatory to planting, and third, it interferes with the development of the crop. The most effective weeders are of the "spear-head sweep" or "duck-foot" type (fig. 16); they are much more efficient in the destruction of weeds than either the disk-harrow (fig. 15) or shovel tooth cultivator; but a caution is necessary in their use: on soils of medium or heavy type, such implements will invariably form a hard, sheared, cultivator sole at the depth of penetration, a circumstance to be avoided, since it neutralizes the beneficial effects of deep plowing. But this undesirable condition is easily and effectively remedied by the occasional use of a deep working chisel cultivator, or killifer (fig. 14). Ordinarily four weedings, supplemented by two

such chiselings, will put the fallow in ideal condition for early planting of seed in the fall.

Prepared in this way, the land need not and should not be plowed preparatory to planting. The deep plowing of twelve months previous, coupled with the long settling period, and frequent surface working, will have given the seed bed the depth and texture necessary to a

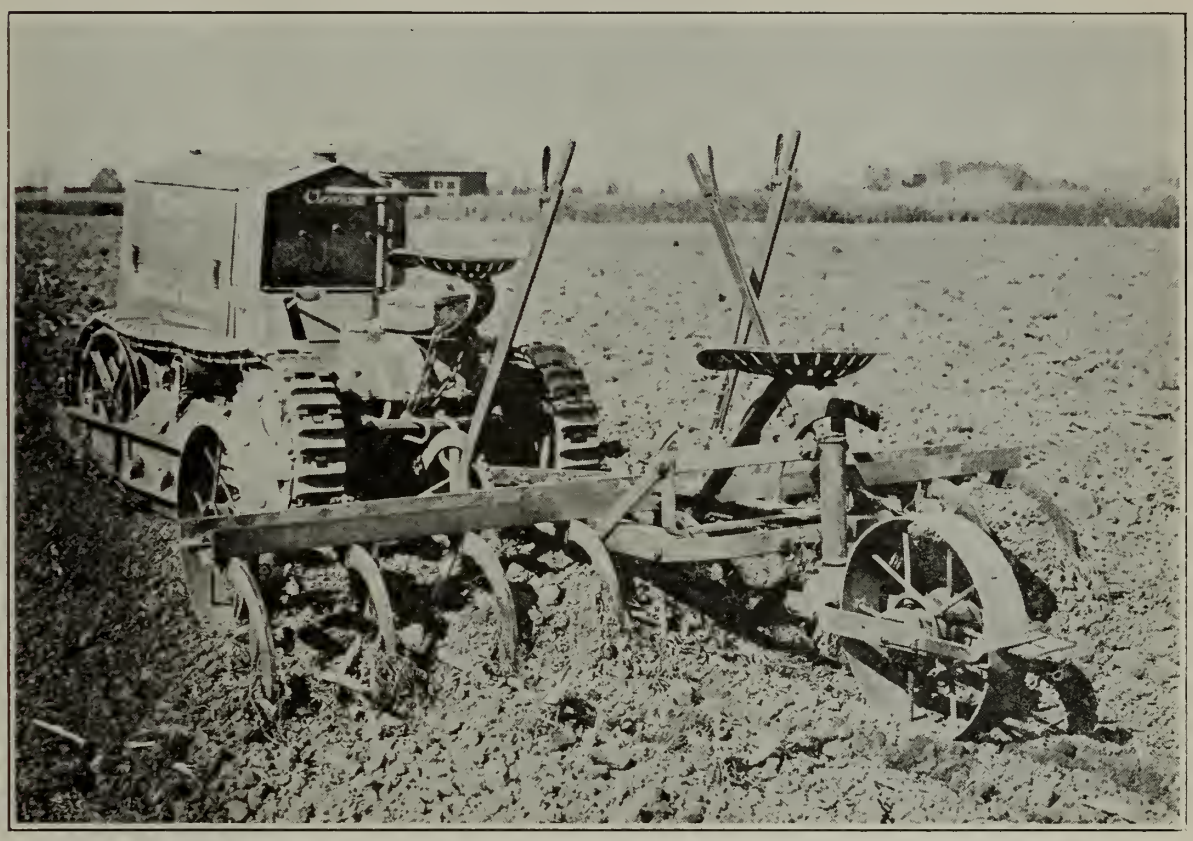

Fig. 12.—Weeding the summer fallow at the University Farm. The implement shown carries nine 6-inch "duck-foot" sweeps, which are set to penetrate four inches. It is more effective than the disk in cleaning the fallow, but it liable to pack the soil at the depth of penetration, in which case it should be followed by the chisel (fig. 10) to break up the sole.

vigorous deep and extensive root development, and by the destruction of weeds will have made further plowing unnecessary.

How to Prepare Land for Annual Cropping.—Deep plowing is an essential adjunct to successful annual grain cropping; but to be of immediate benefit it must be accomplished early in the fall, and indeed may be an actual detriment if performed late in the winter. Consequently we have no sufficient reason to dissent from those who advocate shallow plowing, so long as they insist upon plowing late in the winter or early in the spring. In order therefore, to advance the plowing date as much as possible, the stubble should be thoroughly disked soon after harvest. This treatment will cause moisture to collect near the surface, and often in sufficient quantity to make smooth plowing possible even before the first rains. Dry summer

plowing, before the soil is moist enough to scour and pulverize, is objectionable excepting on the lighter, freer working soils. Land which has been turned up in large hard lumps often remains in that condition until well into the winter or early spring, and even though finely pulverized at the surface, may remain rough and lumpy at the bottom of the furrow (fig. 17).

Circumstances often prevent the strict adherence to a definite programme of field work, but with certain exceptions, the ideal fitting of land for the annual production of barley should consist of a stubble disking in June, followed by ten-inch plowing in November, followed by a four-inch plowing a few weeks later, followed by disking, harrowing, and seeding as soon thereafter as possible. But if only one plowing is contemplated, and the land is weedy, we may safely grant that this single plowing should preferably be done late in the winter, because of the weeds, and that it should not exceed six inches in depth, because of the loss of moisture. It is also important that it be followed closely by a weighted disk to consolidate it, and the deeper and later it is plowed the more thoroughly the disking should be done. In this manner the disk accomplishes, though less effectively, what the winter rains accomplish for fall plowing: Underlying all this is the principle that the soil moisture is incapable of rising to the surface unless the soil is finely pulverized and firmly settled, and consequently the root zone, if unconsolidated, becomes insulated from the lower reservoir of soil moisture, and is subject to rapid drying, even though the sub-soil remains abundantly supplied with moisture.

The statements made above form the basis for a rational system of land preparation for grain cropping on the dry lands of interior California, and if followed with discretion, should result in an early, moist and perfectly prepared seed bed, deeply worked, well settled, finely pulverized below, and coarsely granular at the surface.

At What Season to Plant Barley.—The barley planting season of California extends over a nine-months period, from September 1 to June 1; but the principal planting season is from December 1 to February 1. Four types of land in California are suited to the spring planting of barley: first, the mountainous districts with their severe winter climates; second, the winter flood areas where fall seeding would "drown out"; third, surface irrigated land, and fourth, sub-irrigated lands which remain well stocked with moisture throughout the summer. Taken together these four types of land produce less than 15 per cent of the California barley crop, the remainder and larger portion being grown on dry land is wholly dependent upon the winter rains for its moisture supply. On land of the latter class

the barley planting season extends from November to March, but only in rare seasons of more than normal spring rain, do plantings after January 15 succeed so well as those made prior to December 15. As a rule, all circumstances being the same, the longer the barley plant is in the ground, the more food it is able to procure from it, and the greater the return it is capable of producing. In an extended series of experiments at the University Farm, it has been definitely ascertained that November and December planted barley outyields January and February planted barley on an average of 5 sacks (10 bushels)

Fig. 13.—An example of a poorly prepared summer fallow. The land has been left in the stubble all winter, and "plowed dry" the following June. It is a heavy soil and has turned up in large lumps which no amount of working will reduce. Land prepared in this manner must be replowed before planting. Such fallowing is wasteful of moisture and fatal to the production of high yields.

per acre, and that November planted barley outyields March planted barley by a still greater margin. In the drier districts to the south, the differential in favor of fall planting as compared with spring planting is still greater.

The following clipping, taken at random from a California paper, speaks eloquently of the planting practice and its effect upon the crop as it exists in California today. It is only one of the numerous items of a similar character which have frequently appeared in our papers:

PORTERVILLE, April 21, 1915.—Worth literally millions of dollars to grain growers a half-inch of rain soaked southern Tulare County today. The storm came in the nick of time to save a half-million bag crop of wheat. It practically assures a fine grain crop over the entire dry farming area of this portion of the valley.

Unfortunately, opportune spring rains do not always occur "in the nick of time" to save the crop. Seven out of ten seasons in California are dry spring seasons. Spring-planted grain is of course dependent upon spring rains to carry it to maturity, while fall-planted grain makes its principal growth during the winter and is independent of additional spring rainfall for its ripening process; in fact, spring rain may be an actual detriment to it. The only valid objection to fall planting is, that occasionally a heavy shower in April or May, coincident with the filling process, may occasion losses through lodging, but such losses are never so disastrous as those suffered by spring-planted grain in dry-spring years.

Notwithstanding these facts, opinion in the Sacramento Valley generally is in favor of spring planting for barley, and so long as this sentiment prevails, unsound as it is, the wider use of the variety Mariout, for reasons previously discussed, should be encouraged.

The crop season of 1918–1919 was an exceptional one in that a rainfall of 3.98 inches on September 10 made it possible to fit the ground and plant barley on dry land during September and October, several weeks in advance of the usual earliest possible planting date (fig. 18). In fact, no previous season at the University Farm has afforded an opportunity to determine the effect of such extremely early planting upon the yield of barley, and while the experiment quoted is a solitary one, the results are strictly comparable and consequently valuable. The land was fallowed during the previous summer, and was prepared for planting by disking. "Four Thousand" barley, a pedigreed strain of the common sort, was drilled at the rate of 80 pounds per acre in each instance.

TABLE 12.—YIELD IN BUSHELS AND SACKS PER ACRE, OF "FOUR THOUSAND" BARLEY (CALIF. NO. 2265) PLANTED AT FOUR DIFFERENT DATES AT THE UNIVERSITY FARM, SEASON OF 1918–19.

Time of planting	Date of planting	Yield	
		Bushels	Sacks
Extremely early	Sept. 18th	60.0	(30.0)
Early	Nov. 6th	80.3	(40.15)
Midseason	Jan. 8th	81.5	(40.75)
Late	Mar. 22nd	31.11	(15.55)

Of course, these figures must only be taken for what they are worth; that is, as approximative. There are far too many interfering conditions to allow them to have an absolute value. In a suggestive way, however, the experiment is of unusual interest, as it shows that in this season at least, barley might be planted either too early or too late to secure maximum yields. Hitherto we had held, that the

earlier the planting, the better the yield, but we must now modify this point of view and say that in certain instances at least too early planting may be as detrimental as too late planting. One striking finding is the extremely low yield of the spring planting.

Further interesting relationships are presented in table 13.

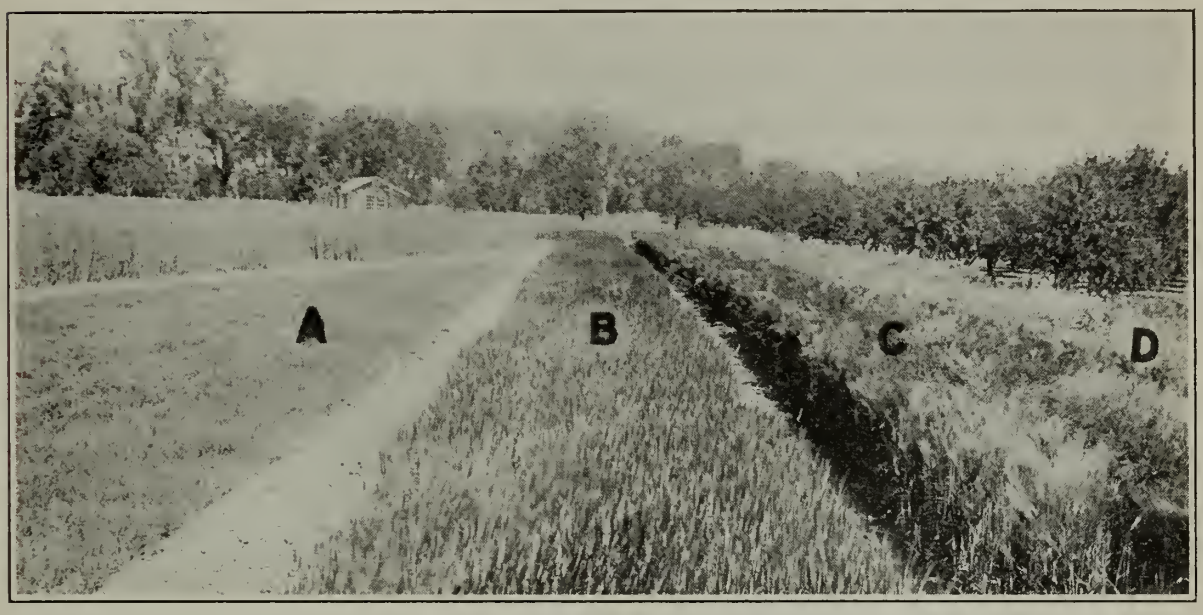

Fig. 14.—Date of planting test with barley at the University Farm. Block "A," planted March 22, yielded 31.11 bushels (15.55 sacks) per acre; block "B," planted January 8, yielded 81.5 bushels (40.75 sacks) per acre; block "C," planted November 6, yielded 80.3 bushels (40.15 sacks) per acre, and block "D," planted September 18, yielded 60 bushels (30 sacks) per acre. September planted barley ripened in 236 days, November planted in 200 days, January planted in 148 days, and March planted in 90 days. For complete data see tables 12 and 13.

TABLE 13.—EFFECT OF PLANTING DATE UPON THE DEVELOPMENT OF "FOUR THOUSAND BARLEY."

Date planted	Av. Height plant in inches	Av. number tillers per plant	Av. length head inches	Av. number grains per spike	Weight of grain lbs. per bushel	Date ripe	First head	Av. number days to ripen	Per cent. lodging
Sept. 18, 1918.....	36	8	1.5	34	37	5–12	3–15	236	0
Nov. 6, 1918.....	52	9	2.25	43	45	5–25	4–10	200	30
Jan. 8, 1919.....	47	8	2.25	54	40	6–5	4–23	148	0
Mar. 22, 1919.....	26	5	1.75	36	36	6–20	5–20	90	0

Summing up these figures, it appears that November and January-planted barley produced the longest straw growth, the longest and best filled heads, the heaviest grain, and the highest yields. Contrary to popular opinion it is also apparent that conditions favorable to the production of tall straw are equally favorable to the production of the most and heaviest barley. The heaviest tillering resulted from November planting, the lightest from March planting. The number

of days required for the crop to ripen is diminished as the planting date is delayed, but late planted barley ripens fully five weeks later than early planted barley. The ranker growth of the November-planted barley occasioned considerably more lodging than either the earlier or later plantings, but the September planting was injured more severely by rust than the later plantings. The yield of the September planting was also considerably reduced by the greater inroads of weeds. November planting yielded a decidedly better quality of grain than either earlier or later plantings.

Manner of Planting.—About 75 per cent of the California grain crop is sown broadcast; about 15 per cent is seeded with machines of the Gorham type, which drop the seed directly from the hopper to the ground without its passing through conductor tubes; and about 10 per cent is planted with grain drills. Broadcasting is rapid and inexpensive, but generally results in reduced yields. The Gorham method is less satisfactory than drilling, but costs the same. Barley may be broadcasted, exclusive of "harrowing in" the seed, at an average cost of from 10 to 25 cents per acre; it may be drilled, using a ten-foot drill, six horses, and one man, at an average cost of 30 to 40 cents per acre, or at a higher rate if smaller drills are used. By attaching five ten-foot drills behind a small tractor, however, the cost of drilling may be reduced to approximately that of broadcasting and the work done as quickly. The average increase in the yield of barley induced by drilling as compared with broadcasting, is 3 sacks (6 bushels) per acre. Considering the cost of the operation as practically the same by the two methods, and taking into account the saving in seed effected by drilling, the net saving amounts to from $3 to $9 per acre, depending upon the price of barley. With $6 as a fair average the net saving from twenty-five acres would equal the retail price of a $150 drill.

Among growers, considerable skepticism still exists concerning the advantages of the drilling method, for the reason that, rude and imperfect as the broadcasting method is, it may under favorable circumstances produce as good results as drilling. It seldom does, however, and the more unfavorable the weather and soil conditions are the greater the yield increment due to drilling. Occasionally dry-plowed land will turn up so rough and lumpy that the drill can not be operated, and broadcasting of necessity is the only recourse; or again, adobe soils may be broadcasted while too wet and sticky to permit the operation of a drill, but these are extreme conditions, not generally met with where careful supervision is given. It is also true that unclean seed, too foul to feed through a drill, may be easily

broadcasted, but it would be a difficult matter to defend the practice on such grounds.

Even a casual examination of a broadcasted barley field, during the early stages of development, will disclose the reasons for the greater productivity induced by drilling. Some of the seed will have been covered too deeply and will have produced sickly debilitated plants,

Fig. 15.—Plowing under a cover crop. Soils continuously cropped to grain for many years respond quickly and profitably to such treatment. Rye, or a combination of rye and vetch should be sown with the first rains and turned under while the soil is still moist in the early spring. The furrow should be deep enough to completely cover the vegetation, and the plow should be followed closely by a weighted disk, set straight, or other firming implement. The land should then be fallowed until planting time in the fall.

while much of it only partly covered, or lying on the surface, will have thrown out temporary roots only, which serve merely to anchor the plant to the ground, leaving the crown high and dry and the coronal or permanent roots undeveloped (fig. 2). Such plants are stranded in dry top soil, so to speak, as the moisture recedes in the spring, and either succumb entirely or produce a small amount of light inferior grain.

Why a practice, so manifestly indefensible as the broadcasting of barley seed, should have retained its almost universal popularity for

so long in California is difficult to explain, except by the servility of the human mind in the presence of established practices or opinions.

Rate of Planting.—Available soil moisture is at the root of this question, but here, of course, several modifying circumstances have to be considered. Too much seed on dry soil will result in a too rapid depletion of moisture, attended by stunted plants, short poorly developed heads, and pinched kernels. Assuming summer fallowing, fall planting, and sixteen inches or more of rain, eighty pounds of plump seed drilled per acre is not too much. Assuming spring planting, and otherwise similar conditions, this should be reduced to sixty pounds, and in southern California, where the rainfall is less than twelve inches, fifty to sixty pounds per acre is sufficient in any case. Irrigated lands may be planted heavily, but overcrowding should be avoided.

If broadcasted, these rates should be increased 25 per cent and poorly-prepared land should be planted more heavily than well-prepared land. Seed dipped for smut, even though it has stood several months, will feed through the drill much more slowly than the same seed prior to treatment. A test at Davis showed that White Australian wheat which had passed through the drill at the rate of eighty pounds per acre previous to treatment, dropped to seventy-two pounds per acre after treatment, when the seed used had stood for several weeks after dipping. The difference here is entirely due to the increased bulk of the seed. The sample in question tested fifty-nine pounds per bushel before, and fifty-four pounds per bushel after treatment. Based upon these tests, a scale which has been calibrated for untreated seed, should be advanced about 15 per cent when treated seed is used, assuming that the same rate of seeding is desired, but more than likely a still greater increase will be required in order to compensate for reduced germination. It should also be remembered that heavy seed flows more freely than light seed of the same variety, and a corresponding adjustment should be made. A test at Davis showed that Chevalier barley weighing fifty pounds per bushel passed through the drill 20 per cent more rapidly than common (Coast) barley, weighing forty-seven pounds per bushel.

It is almost superfluous to add that old or damaged barley should be planted at a heavier rate than new barley of good quality. Badly thrashed seed is damaged more in the process of treating for smut than uninjured seed; and the use of such damaged seed has been a fertile source of trouble in the past.

Spring Harrowing.—It very often happens that barley has not completely shaded the ground prior to the drying and crusting of the

soil in the spring. Under such circumstances the ground loses its moisture rapidly and a hard crust develops about the crowns of the plants. In dry seasons this reacts unfavorably upon the development and stooling of the seedlings, and consequently reduces the yield and quality of the grain. The remedy is to harrow the standing grain before the crust becomes too thick and dry to disintegrate readily. If the grain has been drilled, harrowing should be done at right angles to the direction of drilling. A common wood-frame spike tooth harrow is adapted to the work, and if the grain is beyond the "fourth leaf" little injury will follow. After the ground has become shaded, harrowing is unnecessary, and for this reason November and December-planted grain rarely is in need of such treatment, and Mariout requires it less often than common barley (fig. 8). Unfortunately we have no properly conducted practical experiments to refer to, which are always desirable where a recommended practice is new to a region, but numerous confirming instances have come to our attention. The experience of a farmer near Tracy is especially instructive. His field adjoined the railway right-of-way, and as a fire protection he harrowed out a twenty-foot strip of grain bordering the railway, traversing it several times with a spike-tooth harrow during March when the grain was about four inches high. The season turned out to be a dry one, and a hard crust formed over the remainder of the field. Contrary to his intention, the harrowed grain continued to grow and as a result of the treatment and the retention of moisture which this effected, it far exceeded in production any other equal area in the field.

The common error in attempting to practice spring harrowing, is to delay the work until the crust has become so hard that it can not be broken.

The Choice of Seed.—The question of using good seed is of more importance than farmers are generally disposed to concede. The best seed obtainable is generally the most economical to use. Desirable barley seed is heavy, plump, fully matured, free from injury, and true to variety. Recleaning is necessary to the production of seed of this character, and a systematic use of a good fanning mill will do more to maintain the quality of seed than the importation of seed from other districts. First get a good strain of a pedigreed, high-producing variety, and then maintain its quality by recleaning a portion of it for seed each year. Careful attention to these matters deserves and would repay far more consideration and care than is usually bestowed upon them.

Home Grown vs. Imported Seed.—A popular, but erroneous notion is that barley seed "runs out" when grown continuously on the same

ground for a number of years, necessitating the importation of new seed stocks from some distant locality. How this error has gained common credence is difficult to say; but it is probably another instance of an old accustomed practice which has been accepted from generation to generation without challenge. The truth is, that the longer barley seed is grown in one locality, the better acclimated it becomes, and all that is necessary to maintain it good, is to keep it pure and reclean it thoroughly each year before planting.

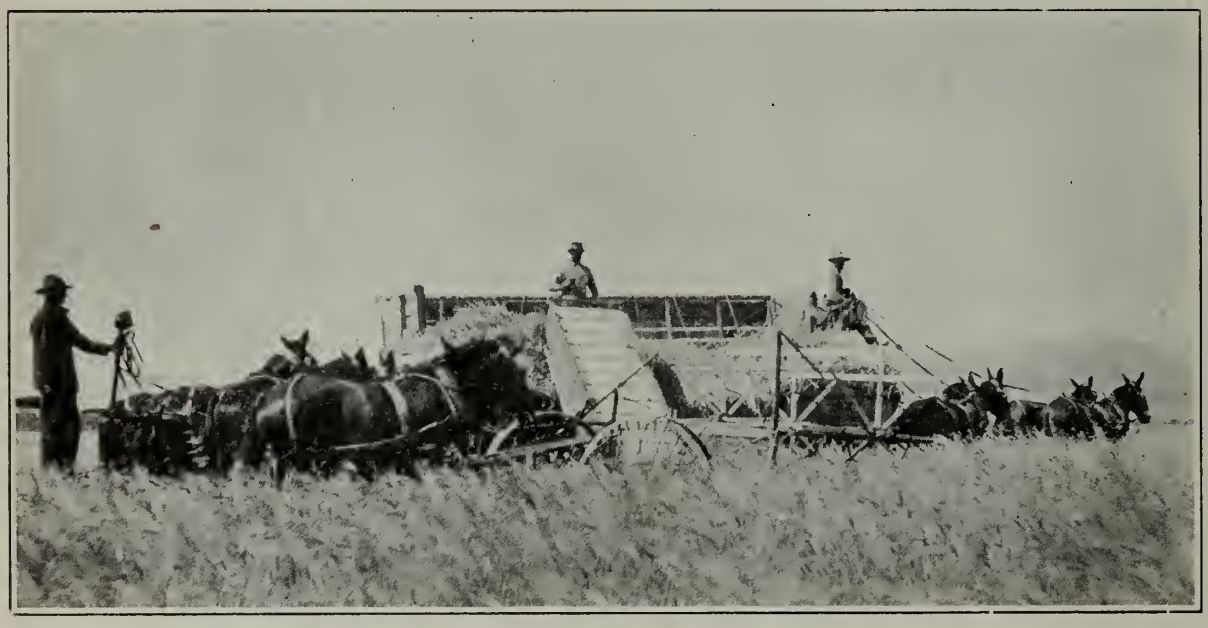

Fig. 16.—A grain header at work on barley in the Salinas Valley, where the high humidity interferes with the operation of a combined harvester. The header method is intermediate between the binder and the harvester in point of efficiency. Grain may be cut with the header before it is fully ripe, yet not so early as with the binder, because it is necessary to defer cutting until the heads are dry enough to stack. The amount of shattering increases proportionately with the length of time the grain remains standing in the field, so that the efficiency of the different harvesting systems is in direct ratio with the time of cutting possible under each system.

HARVESTING METHODS

There are three types of implements employed in harvesting small grains in California. These are the binder, the header, and the combined harvester. The binder and the header serve simply to cut the standing grain preparatory to threshing, while the combined harvester, as its name implies, combines the two operations into one, heading and threshing grain in a single operation.

The combined harvester or "combine," as it is usually termed, is a distinctively Californian product, and was developed along with the bonanza wheat farms at a time when wheat production was undergoing a great expansion, and the efforts of the implement makers were directed toward the development of machinery of large capacity. The

gang plow and the combined harvester were built with cutting bases of unusual length, and all implements were constructed with the object of combining several operations into one, for the purpose of enabling one man to cultivate the greatest possible area. Combined harvesters were used in California as early as 1868, but it was not until about the year 1880 that they came into general use. Stationary threshing machines were used in California before the combined harvester was

Fig. 17.—The binder in operation at the University Farm. By this method cutting is done before the heads are ripe and brittle, and very little shattering results, because the ripening process is completed in the shock where the heads are protected from the weather.

invented, but the combine by virtue of the greater rapidity and cheapness with which it performed the work of harvesting soon replaced practically all other types of harvesting machinery, except in the coastal sections of the state, where it has never superseded the stationary threshing machine, because of the climatic conditions. Although approximately 85 per cent of the California grain crop is harvested by the combined-harvester method at the present time, there is a tendency to return to the stationary threshing machine system; and more binders and headers are being used now than formerly.

The use of the combined harvester is restricted to regions of peculiar climatic conditions. This is true because grain must remain

standing in the field until it has reached the dead ripe stage, and must be completely dry at the time it is cut with the combined harvester. The combined harvester will not handle grain in the dough stage, nor will it perform its work satisfactorily on grain which is slightly moist. For these reasons it has never replaced the stationary threshing machine in the barley-producing section of the Salinas Valley, where the humidity is high, and it has never been used to any extent east of the Rocky Mountains, where showers and high humidities prevail during the ripening period of grain.

Ideal conditions for the combined harvester are found in the Sacramento and San Joaquin valleys. In these great valleys there is as a rule a continuous rainless season of six months, during which grain remains standing in the field without deterioration for weeks after it has passed the customary binding or dough condition.

The fact that the successful operation of the combined harvester depends upon the grain reaching an advanced stage of ripeness while standing in the field, is a disadvantage to the system generally, and results in shattering losses, which are only partly compensated by the lower cost of the operation. Barley which remains standing in the field until ripe enough to cut with a combined harvester becomes very brittle and shatters easily. There is, however, considerable difference in the ability of different varieties of wheat and barley to resist shattering. Club wheat, for example, is notably tenacious of its grain. There are many varieties of wheat which surpass the Clubs in yielding ability, and nearly all of the soft white wheats grown in the Pacific Coast region are superior in quality, and bring higher market prices than the Clubs, yet the single fact that the Clubs do not shatter easily has made them desirable wheats wherever the combined harvester is used.

Since barley has become California's leading cereal, the shattering problem has become more serious than it formerly was, and the aggregate shattering losses are doubtless considerably higher, because barley shatters more readily than wheat, and no barley varieties yet grown, can compare with the Club wheats in non-shattering properties.

A peculiarity of the climate of the Sacramento and San Joaquin valleys, which is partly responsible for the unusually high shattering losses, is the frequent occurrence of strong northwest winds during the harvest season. It is not unusual for a north wind to spring up while harvesting is in progress, resulting in a decrease in yield of from 10 to 50 per cent. Frequently fields which were yielding from twelve to fifteen sacks per acre before the occurrence of a "norther"

yield but five or six sacks per acre after the wind, showing that the wind has whipped out as much or more than half of the grain. In situations where a portion of a field is protected from the force of the wind on the north by a row of trees or group of buildings, the effect of the wind-break may be observed for many rods to leeward by the absence of shattering. That the "northers" are of frequent occurrence during harvest time is proved by the subjoined tables taken from the report of Mr. Thos. G. Blair, Assistant Weather

Fig. 18.—The combined harvester was developed in California in about 1868. To within recent years these implements have been propelled by horse and mule power, but are now equipped with auxiliary gas engines and either drawn by, or mounted on, track-laying tractors. It cuts and threshes standing grain at a single operation, but is limited in its use to grain which is dead ripe and thoroughly dry. It is efficient as a machine, but its defect lies in the fact that grain often shatters badly before it can be used.

Observer, dated at Sacramento, Calif., April 20, 1909. The observations were made at Sacramento and no wind which did not show a maximum velocity of fifteen miles per hour or more was considered a "norther." The tables cover the period from 1902 to 1908, inclusive, and constitute the only complete record which we have for wind directions, durations and velocities.

Summarizing these figures it is found that during the month of June, which is the grain harvest month in California, two "northers" on the average, moving with a velocity of about twenty miles per hour and lasting from two to three days each, have occurred during the period considered.

TABLE 14.—DURATION OF NORTHERS (IN DAYS), SACRAMENTO, CALIF., 1902–1908.

Year	1902	1903	1904	1905	1906	1907	1908
January	2	0	0	0	1	0	0
February	0	4,3	0	1	0	2	2
March	2,4	2	3	2,3	2	2	3,2,3
April	1,3	3,3,2	5,2	2,1	5	4,1	3,3,1,1,2
May	3	4,4,2	2,4,1,5,2	1,1,3	1	2,1,5	2,4,2,3
June	4,2	3,1	3,2,3	0	3,3	4	1,2,3
July	0	3,1	1	6	0	0	0
August	1	1	2	0	0	2	3
September	3,4,2	3,2	4	2,2	2,2	1	4
October	1	2	4	5,1,2,2	5,1,10	4	2,3,2
November	0	0	0	4,2	4,3,2,2	5,2,2,1	0
December	0	0	0	4,3	0	0	0
Annual Duration	33	44	46	47	46	38	51

TABLE 15.—MAXIMUM WIND VELOCITY AND DIRECTION OF NORTHERS

Year	1902	1903	1904	1905	1906	1907	1908
January	33 n.	0	18 n.	0	29 nw.	0	0 .....
February	0	40 nw.	0	16 n.	0	20 nw.	26 nw.
March	28 nw.	15 nw.	15 nw.	20 nw.	16 n.	15 nw.	33 nw.
April	23 nw.	35 nw.	22 nw.	30 nw.	35 nw.	31 nw.	36 nw.
May	45 nw.	40 nw.	36 nw.	36 nw.	15 nw.	25 nw.	29 nw.
June	28 nw.	15 nw.	30 nw.	0	16 nw.	16 nw.	22 nw.
July	0	40 nw.	15 nw.	15 nw.	0	0	0 .....
August	18 nw.	15 nw.	15 nw.	0	0	19 nw.	28 nw.
September	32 nw.	40 nw.	16nw.	20 nw.	22 nw.	15 nw.	24 nw.
October	24 nw.	24 n.	24 nw.	38 nw.	33 nw.	29 nw.	34 nw.
November	15 nw.	0	0	40 n.	36 n.	28 nw.	0 .....
December	0	0	0	27 nw.	0	0	0 .....
Annual	45 nw.	40 nw.	36 nw.	38 nw.	36 n.	31 nw.	36 nw.

Heavy shattering losses are the rule wherever the combined harvester is used, but the actual loss in any specific case may vary widely, depending chiefly upon the frequency and velocity of the wind during the ripening period. Some farmers contend that a certain amount of shattering is desirable because the stubble contains enough grain to provide good pasturage for cattle, sheep and hogs, and that the grain which is not gleaned by the stock may then be harrowed into the ground in lieu of sowing seed for the succeeding crop. This is the "volunteering" system of grain farmers which is extensively practiced in certain parts of California and has been possible because of the wastefulness of the combined harvester system. As many as seven successive crops have been produced by this method without reseeding the land. Barley stubble left by the combined harvester rents for from 10 cents to $1 per acre for pasture, the specific rate

depending upon the amount of shattered grain it contains and the general scarcity of feed. In this connection it is a significant fact that stubble land left by the binder is generally considered valueless as pasture land because it contains practically no shattered grain for stock to glean. Both practices—pasturing stubble, and voluntering—are of doubtful advantage to the farmer and are at best poor justification for the wastefulness of the combined harvester system.

Attempts to reduce shattering losses, particularly in the more exposed situations, are frequently made by resorting to the practice of dragging down standing grain before it has reached the critical dead ripe stage. This operation, which is accomplished by dragging a plank over the field, is designed to flatten the grain sufficiently so that the heads will lie close to the ground, sheltered from the wind during the ripening period. It also serves the useful purpose of lodging the grain uniformly, so that it may be more easily harvested than if allowed to lodge naturally. That such drastic treatment is considered necessary is in itself evidence of the seriousness of the shattering problem. While the dragging-down of grain is considered helpful in reducing shattering and preventing excessive losses, the benefits of the practice are largely offset by the losses incurred incident to the dragging process, and by the additional fact that much of the grain is not picked up by the harvester because the sickle of the machine cuts much of the bent-over straw twice, leaving the head on the ground.

The grain binder system of harvesting largely eliminates shattering losses, because by this method grain may be cut before it has become dead ripe. Grain is customarily cut with the binder while the kernels are in the "dough." At this stage of development the heads are still somewhat sappy, so to speak, and not easily shattered. The ripening process is completed in the shock or stack and the ripened grain is taken to the threshing machine tightly bound in the bundle, so that at no time during the process is the ripened grain exposed to the wind.

The header method of harvesting is intermediate between the combined harvester and the binder in point of efficiency. Grain may be cut with the header before it is fully ripe, yet not so early as with the binder, because it is necessary to defer cutting until the heads are dry enough to stack without danger of heating and spoiling.

Grain may safely be cut with the binder from a week to ten days earlier than with the header, and from two to three weeks earlier than with the combined harvester. The amount of shattering increases with the length of time the grain remains standing in the field, so

that the relative efficiency of the three systems is correlated with the time of cutting under each system.

The comparative efficiency of the binder and combined harvester systems of harvesting was strikingly illustrated during the 1915 harvest season, by the experience of a farmer near Madera, who used both methods in harvesting his crop, under conditions which admitted of direct comparison. Adjoining fields of barley were harvested, one with the binder, the other with the combined harvester, and although the two fields were identical in all respects and promised to yield the same amount of grain per acre, the field cut with the binder returned twenty-two sacks per acre, while the one cut with the combined harvester returned only fifteen sacks per acre—a difference of seven sacks per acre, amounting to about 30 per cent of the entire crop in favor of the binder system.

During the 1915 harvest season measurements were made at Davis to ascertain accurately the losses sustained through shattering incident to the use of the combined harvester, and the results obtained tally closely with those of the Madera farmer. Field No. 2, consisting of 108.87 acres, was selected for the experiment. The field was sown to Beldi barley in the fall of 1914. On the 21st of June, 1915, the crop was cut with the combined harvester. The machine employed was an itinerant machine of a common type and was engaged in harvesting grain in the neighborhood at the flat contract rate of $75 per day. By this method of harvesting the field yielded at the rate of 24½ sacks of barley per acre, but the stubble contained much shattered grain and it was evident that a much higher yield would have resulted if a more efficient method of harvesting had been employed. Immediately after the harvest a careful survey was made of the entire field, and three plots, each representing an average condition with respect to the amount of grain remaining on the ground, were located in various parts of the field. Spots where the grain had lodged and the loss of grain was consequently high, were not included in the average. The calculated loss per acre, based upon the weight of grain collected from these plots is conservative, and is thought to be well below the actual loss. The results of these determinations are recorded in table 16.

The loss of grain in this instance averaged 6.62 sacks of 110 pounds each per acre; that is, the combined harvester recovered 24.5 sacks per acre out of a possible 31.12 sacks per acre, failing to recover 21.2 per cent of the crop.

The extravagance of this system is generally admitted, but it has retained its popularity in California because it has been practically

indispensible under the extensive system of grain farming practiced. But as the grain ranches are being reduced in size, and the value of land is increasing, the question of efficiency of production and higher net returns per acre is receiving more thought.

The production of barley at a fair profit on land valued at $100 per acre is rarely accomplished in this state under present methods of farming and with pre-war prices. Investigations prior to the war

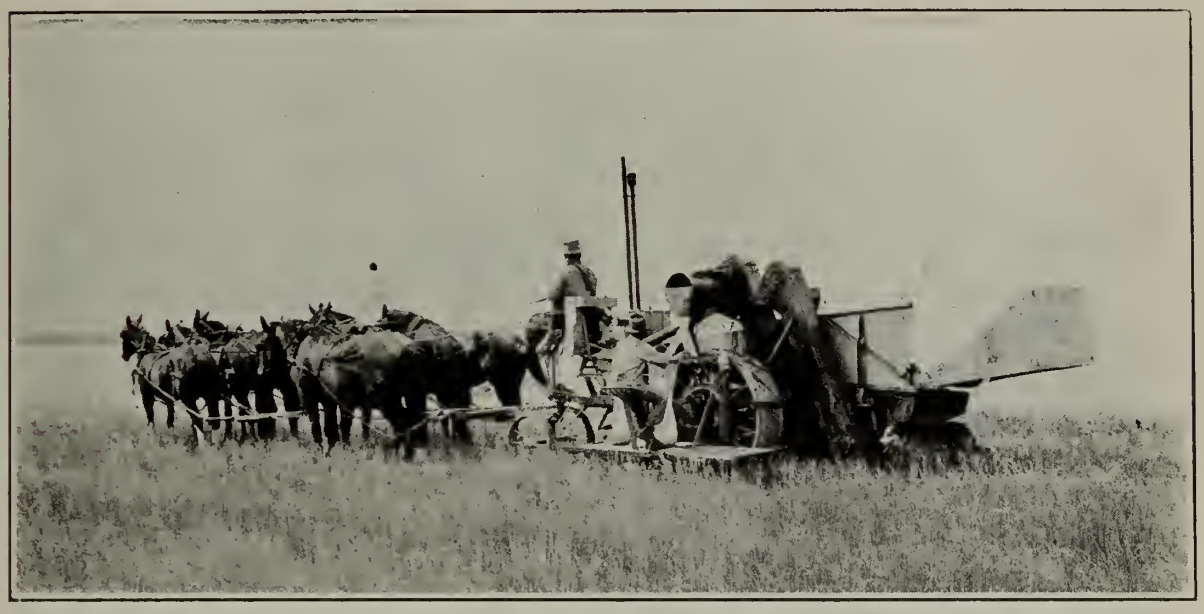

Fig. 19.—The small combined harvester made its first appearance in California in about 1917, where it is estimated that about 800 were in use in 1919. It is equipped with an auxiliary engine and may be propelled by a small tractor or from eight to twelve horses. It is capable of cutting and threshing from fifteen to twenty acres per day. From the standpoint of efficiency it is in no way superior to the larger machines, but because of its smaller size, and cost, it is better adapted to smaller acreages, and enables the small producer to own his "outfit" and makes him independent of the itinerant machines which are difficult to obtain at the time they are most needed.

showed that the greater part of the grain land in California valued at $100 an acre or more was returning less than 4 per cent interest on the capital invested when devoted to the production of barley. E. C. Chilcott, of the United States Department of Agriculture, after an extensive series of investigations in grain production in the great

Table 16.—Grain Left in Stubble After Harvesting with the Combined Harvester

Plot	Grain remaining on ground in lbs. per acre	Grain* remaining on ground in sacks per acre	Value of grain remaining on ground at $1.10 per sack (pre-war normal price)
1	506.0	4.60	$5.06
2	848.0	7.70	8.47
3	831.6	7.56	8.31
Average	.....	6.62	8.28

*An average sack of barley weighs 110 pounds.

plains area of the United States, concluded that a reduction in the cost of production is a more important factor in determining profits in grain farming than increasing yields by culture methods. But this conclusion does not necessarily hold under California conditions. In this state the cost of grain production has been reduced below the most profitable point, sacrificing yield to such an extent that the margin of profit has been almost eliminated.

The combined harvester has been an important factor in reducing the cost of producing grain, but at a great sacrifice of yield. There is a growing sentiment among farmers that the binder system is more economical as measured by the net returns per acre. That this sentiment exists is manifest from the fact that the number of binders used in this state is constantly increasing, and it is not unusual to find all three types of harvesting machinery—binders, headers, and "combines"—working within sight of one another.

Because of the varying conditions under which grain is grown and harvested in California, a comparison of the various harvesting systems, from a money standpoint, which would be applicable to the state as a whole is impossible. But the general relation which exists between the binder and combined-harvester systems is shown for one specific instance in table 17. The basis of this calculation are the data collected at Davis and previously referred to (table 17).

TABLE 17.—AVERAGE COST OF PRODUCTION AND NET PROFIT FOR PRODUCING BARLEY IN CALIFORNIA. THE COMBINED HARVESTSR VS. THE GRAIN BINDER

	Combined Harvester cost per acre[4]	Grain Binder cost per acre[4]
[1]Plowing and harrowing with tractor (usual contract price)	$1.75	$1.75
[1]Seeding with broadcast seeder	.15	.15
Seed	1.00	1.00
[1]Harrowing in seed	.25	.25
[1]Harvesting with combined harvester (contract price for 24½ sack crop)	3.40	.....
Piling sacks in field at 1 cent each	.24	.....
Cutting with self-binder (contract price for 30 sack crop)	.....	1.00
Shocking in the field	.....	.25
Binder twine (30 sack crop)	.....	.30
[1]Threshing, including hauling from shock	.....	4.30
Twenty-five sacks at 8½ cents each	2.10	.....
Thirty-one sacks at 8½ cents each	.....	2.71
Hauling five miles, 10 horses, 1 man, 8 tons per load, 20 miles per day	.66	.81
Weighing and storing in warehouse to Jan. 1 at 75 cents ton	1.01	1.24

[1] The items of plowing, seeding, harrowing, harvesting, binding, and threshing, are charged at average contract prices and are subject to variation.

TABLE 17.—(*Continued*)

	Combined Harvester cost per acre[4]	Grain Binder cost per acre[4]
Field insurance 90 cents per $100.00 value, 2 mo	.24	.30
Insurance in warehouse 3% on $1.00 per sack value	.73	.90
Interest at 8% on 1,000 acres at $125.00 per acre; 10 horses, $1750; implements and wagons, etc., $600 and buildings $2,000	10.34	10.34
Depreciation on equipment, stock, implements, 10% and on buildings, 5%	.33	.33
Incidental expenses—selling, etc	.50	.50
Total cost of production per acre	22.79	26.13
[2]Gross value of 24½ sacks of barley at $1.10 per sack	26.95	.....
[2]Gross value of 30.12 sacks of barley at $1.10 per sack	.....	33.13
[3]Net returns per acre, using the combined harvester	4.16	.....
[3]Net returns per acre, using binder and stationary threshing machine	.....	7.00
[3]Net saving per acre due to the use of grain binder	$2.84	.....

[2] A total yield of 31.12 sacks of barley is assumed in each instance, but the amounts recovered are 24.5 and 30.12 sacks per acre, respectively, for the combined harvester and the binder. The shattering loss of 6.62 sacks per acre for the combined harvester is based upon the field determinations at Davis previously quoted. The shattering loss of one sack per acre for binder, including loss in threshing, is based upon observations also made at the University Farm on plots cut with the binder.

The total yield of 31.12 sacks of barley per acre used in the calculation is somewhat higher than the general average for the state, but is a yield which good farmers, under a system of biennial cropping, on good land, frequently obtain, and is used here principally because it is the yield upon which the actual shattering determinations were made. Although it may be held that the shattering loss was unusually high in this case because the yield was above average, observations made in various parts of the state would indicate that the contrary is true, and that the percent of shattering is usually higher in the case of the lower yields, except where too thick seeding has resulted in overcrowding and lodging.

[3] The net return is the amount remaining after deducting all charges, plus 8 per cent interest on capital invested, from the gross receipts.

In this instance the difference in cost of production amounts to $3.34 per acre in favor of the combined harvester. But the difference in value of the crop amounts to $6.18 per acre in favor of the binder, leaving a balance of $2.84 per acre in favor of the binder system.

[4] Prices and costs are taken at pre-war average normal rates.

A second problem, more vital to the grain farmers of California than the shattering problem, is that of developing an adequate system of crop rotation. This is a question upon which harvesting methods have a direct bearing. As previously stated, grain may be cut with the binder, removed from the field and stacked, from two to three weeks before it is ripe enough to cut with the combined harvester. This early removal affords an opportunity to follow the grain crop with some quick-maturing summer crop the same season. Under favorable circumstances, beans, cowpeas, Indian corn, grain sorghums, or Sudan grass may be planted after the removal of the grain crop late in May or early in June, and matured in the autumn. There is

much land in California where succession cropping of this character is feasible.

A third problem of considerable moment to the California grain farmer, is the control of weeds. The weeds most common to the grain fields of the state in the order of frequency of occurrence, as determined by the analysis of 200 samples of grain from various parts of the state, are as follows: wild oat (*Avena fatua* and *A. barbata*), darnel (*Lolium temulentum*), buckthorn (*Amsinckia intermedia*), tarweed (*Hemizonia* sp.), canary grass (*Phalaris paradoxa*), and mustard (*Brassica campestris*). Sweet clover (*Melilotus indica*), wild radish (*Raphanus sativus* and *R. raphanistrum*), Napa thistle (*Centaurea solstitialis*), and chess (*Bromus hordeaceous* and *B. secalinus*), are also troublesome in certain localities. Under the binder system many of these weeds are cut before they have ripened seed; under the combined harvester system, they not only ripen seed, but many of them ripen seed and drop it upon the ground before the crop is ready for harvesting.

DIGEST

1. More than 99 per cent of all barley grown in California is of the "Coast" or common variety.
2. Extensive experiments at the University Farm have shown that other varieties are more productive than "Coast" under special circumstances.
3. Mariout barley, an Egyptian importation, is a better variety than "Coast" barley for the interior valleys of California.
4. There were 3000 acres of Mariout grown within a radius of twenty miles of the University Farm at Davis in 1919.
5. Mariout is more drouth-resistant than common barley.
6. Mariout succeeds better than common barley when spring planted.
7. Mariout uses less soil moisture than common barley.
8. Mariout shatters less than common barley.
9. Mariout is well adapted to the Tulare Lake region and escapes harvest floods by ripening two weeks in advance of common barley.
10. Mariout is well adapted to double cropping because it occupies the land for a shorter period than common barley.
11. Mariout produces less, but a better quality of hay than common barley.
12. Mariout does not thrive so well as common barley in cool mountainous districts.

13. Mariout does not stand winter-flooding so well as common barley, but Tennessee Winter barley yields better than either under such circumstances.

14. Mariout develops more rapidly than common barley.

15. Mariout ripens from ten to twenty days in advance of common barley.

16. Mariout produces a higher percentage of grain and a lower percentage of straw by weight than common barley.

17. Mariout may be easily distinguished from common barley by numerous minor differences.

18. Mariout has a higher average yield record than common barley in a nine-year test at the University Farm.

19. Mariout has the highest individual yield record of any variety tested at Davis. It produced 126.6 bushels (63.35 sacks) per acre in 1911.

20. Mariout has decisively outyielded common barley in dry years.

21. Mariout has decisively outyielded common barley in spring planting tests.

22. Mariout has outyielded common barley in a four-year test at the United States Plant Introduction Garden at Chico.

23. Mariout has been outyielded by common barley in a five-year test at Highmore, S. D., excepting in drouth years.

24. Mariout has outyielded common barley in an eight-year test at Moccasin, Montana.

25. Mariout has outyielded common barley in seven out of the eight years that it has been grown at Moro, Oregon.

26. Mariout has outyielded common barley in a three-year test at Aberdeen, Idaho.

27. Mariout has been outyielded in a five-year test in the frosty climate of Burns, Oregon.

28. Mariout has been more productive than common barley at five of the seven western experiment stations where it has been grown and has outyielded common barley at all of them in drouth years.

29. Mariout equals common barley in malting value.

30. Biennial cropping with barley is more profitable than annual cropping where the seasonal rainfall is less than sixteen inches.

31. Annual cropping with barley is more profitable than biennial cropping when the annual rainfall exceeds eighteen inches.

32. Disking the stubble immediately after harvest is an important aid in conserving soil moisture.

33. Fall plowing in California should be from eight to ten inches in depth.

34. Spring plowing in California should be from four to five inches in depth.

35. The fallow should be established early in the spring.

36. Dry summer plowing is detrimental.

37. The surface mulch should be granular.

38. The weed cutter should be supplemented by the chisel on summer fallow.

39. The disk harrow is not an efficient weeder and pulverizes the soil too finely.

40. Where grain is grown continuously the land should be disked after harvest and plowed twice prior to planting; once deeply in November and once shallowly a few weeks later.

41. Spring plowing should be supplemented by disking to settle the soil.

42. Fall (November–December) planting is preferable to spring (February–March) planting.

43. No advantage is to be gained by planting prior to November 15.

44. Early planted barley produces the longest straw, the longest and best filled heads, the heaviest grain and the highest yields.

45. The number of days required to ripen is diminished as the planting date is delayed.

46. September plantings rusted more and were weedier than later plantings.

47. The yield of barley may generally be increased 3 sacks (6 bushels) per acre by drilling as compared with broadcasting.

48. The rate of planting barley depends chiefly upon the moisture supply.

49. Grain treated for smut flows through the drill more slowly than untreated grain.

50. Heavy grain flows through the drill more rapidly than light grain.

51. Treated grain should be planted more thickly than untreated grain.

52. Grain should be harrowed in the spring to prevent crusting.

53. Plant heavy recleaned seed, of a high producing strain true to variety, and free from injury.

54. Use home-grown seed in preference to seed imported from a distance.

55. The "combined harvester" is limited in its use to regions of low humidity, and where rain does not occur during the harvest season.

56. Grain must remain standing in the field until it is dead ripe before it may be cut with the combined harvester.

57. On an average, two strong north winds occur during the harvest month of June in the Sacramento Valley.

58. Ripe grain shatters badly when exposed to these winds.

59. The average shattering loss of barley where the combined harvester is used is about 6.56 sacks or 13 bushels per acre.

60. Shattering losses may be eliminated by the use of the self-binder which cuts the grain while in the dough and too sappy to shatter.

61. It cost before the war on an average of $22.79 per acre to produce and sell an acre of barley using the combined harvester system.

62. It cost before the war on an average of $26.13 to produce and sell an acre of barley using the binder system.

63. The gross value of the average crop per acre produced under the combined harvester system is $26.95. That produced under the binder system is worth $33.13.

64. The average net saving per acre due to the use of the grain binder is $2.84, under pre-war conditions.